SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

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JUNE, 1955—VOL. 27, No. 6

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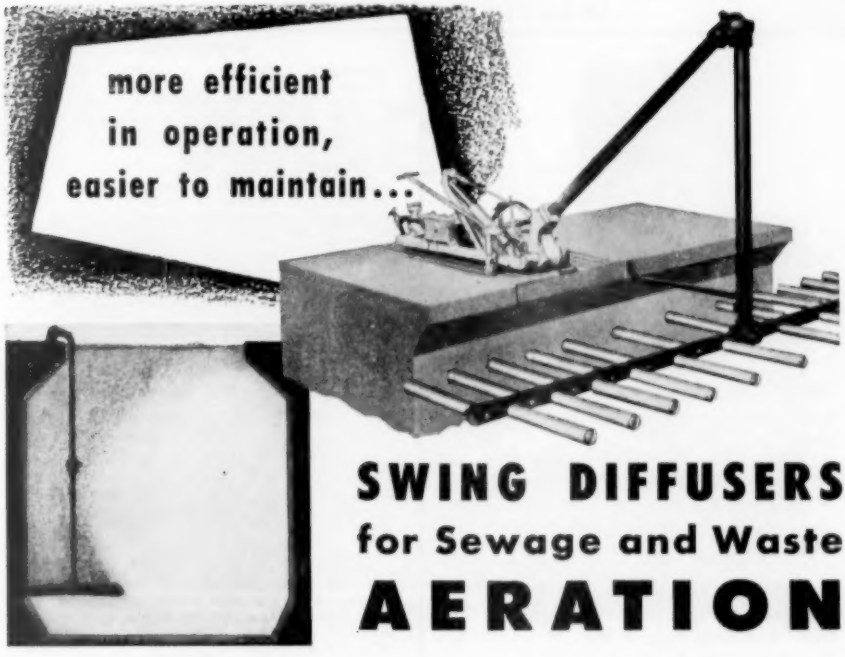

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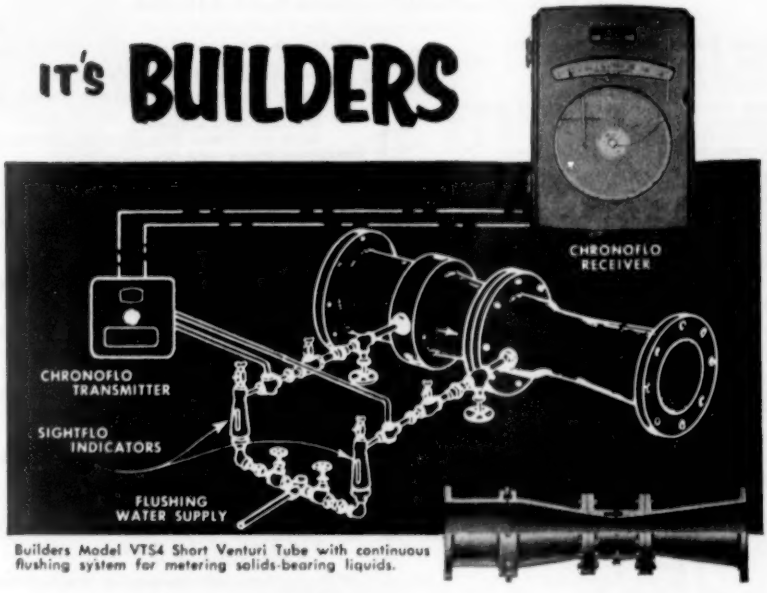

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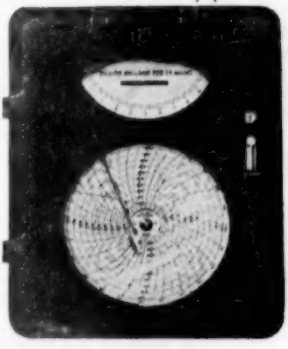

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Missouri Water and Sewerage Conf.	Connor Hotel, Joplin, Mo.	Sept. 25–27, 1955
Oklahoma Water, Sewage and Industrial Wastes Conf.	Oklahoma A and M College Stillwater, Okla.	Oct. 5–6, 1955

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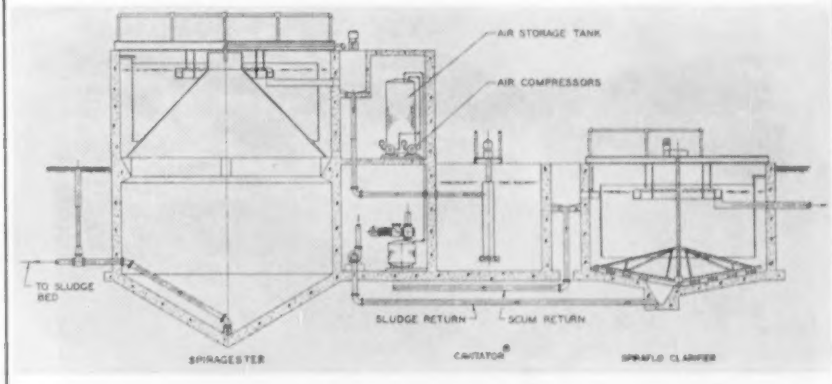

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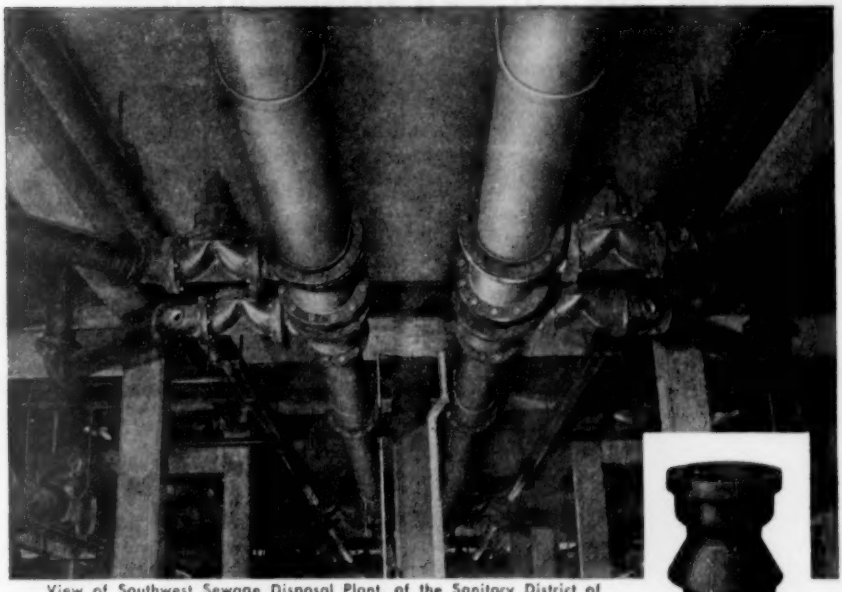

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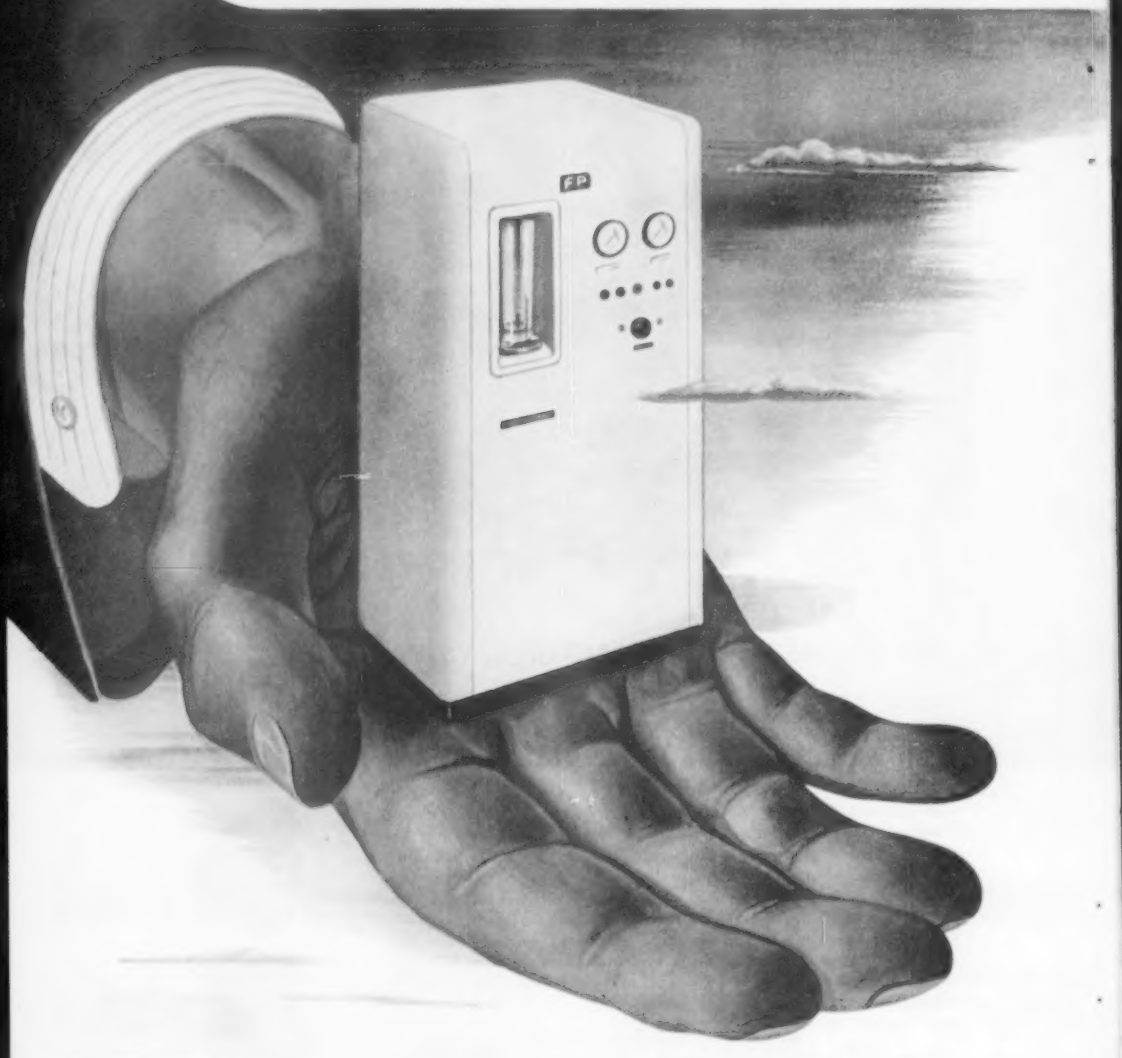

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"Because there are so many good and valid reasons why our Chlorinator merits your deep consideration, I'm signing this advertisement. I am Kermit Fischer, President of Fischer & Porter Company.

Fischer & Porter Company has been in business since 1937, making chlorine control systems for all of the eighteen years since then. In 1949, after years of experimentation and development, we put our first 'packaged unit' chlorinator into service at Winter Park, Florida waterworks—where it has been operating successfully ever since. In May of 1952 we retooled our chlorinator production, incorporating into our basic design all the improvements made possible through the experience gained at Winter Park and some fifty other installations. Now there are more than 1000 of the new model F&P Chlorinators in daily use—and all our customers tell us it is the best chlorinator they have ever used.

HERE ARE SEVEN REASONS WHY I CAN MAKE THIS GUARANTEE OFFER TO YOU WITH CONFIDENCE . . .

1. SAFEST . . . The F&P Chlorinator is completely safe because it uses instantaneously operating mechanical instrument type safety devices. Any malfunctioning shuts off the chlorine supply instantaneously—but the chlorinator automatically starts operating again when the trouble has been corrected. There are no bell jars—exposed or otherwise—with water seals, so there are not the time delays these outmoded components introduce to the safety system.

2. MOST DEPENDABLE . . . Many F&P Chlorinators have operated for over a year at a time without being shut down for any repairs or replacement parts or for cleaning. Even connecting chlorine to the water inlet and water to the chlorine inlet did not faze one customer's chlorinator. After the connections were reversed, the chlorine system sucked itself dry and the chlorinator started up automatically.

3. MUCH LOWER FIRST COST . . . Simplified design, mass production methods, *mechanical* principle of operation, modern instrument engineering, make it possible to supply the new F&P Chlorinator at far lower first cost than the old hydraulic bell jar chlorinators.

4. MUCH LOWER MAINTENANCE COST . . . Not one, not a dozen, but *every* present user of F&P Chlorinators has stated unequivocally that the F&P Chlorinator cuts the maintenance bill to nil—whereas formerly maintenance cost was a major item.

5. NO CORROSION, NO SCRAPING, NO PAINTING . . . Because the cabinet is made entirely of fibre glass—without any internal metal bracing—it cannot corrode, does not have any paint or other finish coat to be renewed. *All* the internal parts are also completely resistant to attack by chlorine, by water or wet mixtures of the two so there is nothing to deteriorate, nothing to scrape, nothing to repair.

6. SIMPLEST TO OPERATE . . . The F&P Chlorinator is so simple that no skill is required either to operate or install. No foundation, no bolting. Just attach piping to the connections labeled 'chlorine,' 'water,' 'drain' and 'vent'—then turn on the chlorine and water valves (either one first) and you're off. Anybody can do it. Anything he does wrong (if he can find something wrong to do) simply shuts down the chlorinator.

7. PROVEN IN USE 1000 TIMES OVER . . . Sales of F&P Chlorinators have increased by leaps and bounds. Over 1000 present users are all saving money day in and day out.

These are provable and proven facts. We can give you every evidence you need of user satisfaction. But I still want you to make up your mind on the F&P Chlorinator, by actual test, *under your own operating conditions.*

All I ask is that you write to me now. Don't wait for repair bills or breakdown to start you thinking about better chlorination equipment. Merely tell me your chlorine capacity requirements, your ejector water supply pressure, your solution discharge pressure and I'll do the rest. You'll be under no obligation whatsoever. I stand on my faith in our Chlorinator. I know that it will win your enthusiastic support, that it will outperform any other chlorinator ever offered. All I ask is that you convince yourself—by trying it at no cost to you.

Will you write to me today—and ask me to prove what I say—*right in your own plant*—under your own operating conditions?"

Kermit Fischer
President.

complete process instrumentation

FISCHER & PORTER CO.

1165 Fischer Road, Hatboro, Penna.

18 YRS. EXPERIENCE SUCCESSFULLY MANUFACTURING CHLORINE FLOW METERING EQUIPMENT

A School? No!

*This plant was designed by Henry W. Taylor, Freeport, N. Y

It's an

INCINERATION PLANT

serving Hempstead, N. Y.

- Large but not an eye-sore
- Efficient and flexible

Serving some 450,000 people, this plant provides an excellent example of the way larger communities are handling their refuse problems. Land-filling can no longer be tolerated in the suburban areas and should not be tolerated *anywhere*. Yet, there's no need to have an incinerator plant that's offensive to the nose and eye. Modern design and modern operation take care of the nuisance factors.

For this Hempstead plant, we furnished four Morse Boulger Mechanically Stoked Furnaces for handling up to 700 tons of refuse per 24 hours. Waste heat boilers recover much of the heat and provide steam for two 1000 kw. turbo-generators. Our engineers also furnished the crane charging equipment, stacks, fly ash removal unit and ash removal conveyor.

What we did to help in this Hempstead project we can do to help you...working with your sanitation engineer or your consulting engineer. The point to keep in mind is that your community, too, can have clean, efficient, nuisance-free refuse disposal in a modern incineration plant such as this Morse Boulger plant.

MORSE BOULGER DESTRUCTOR CO.

80 FIFTH AVENUE • NEW YORK 11, N. Y.

Specify IOWA for every job

Iowa's complete line of valves for treatment plants assures you of efficient operation, low maintenance cost, and replacement parts when needed in years to come.

IOWA CHECK VALVES—Swing gate type for use in either horizontal or vertical pipe lines. Bronze trimmed throughout. Stainless steel hinge pins. Leather or rubber faced gates, or solid bronze, as desired—aluminum gates available for air service.

IOWA MEDIUM AND LOW PRESSURE VALVES—either non-rising stem or outside screw and yoke types. Designed as carefully as those conforming to A.W.W.A. specifications but with lighter construction for lower pressures.

Write TODAY for descriptive literature

IOWA FLAP VALVES—all iron; can be furnished with bronze hinge bolts or fully bronze mounted—including bronze bolts, flap ring and seat ring—when required.

CLOW HYDROSTATIC RELIEF VALVES — commonly used in bottom of concrete tanks to prevent ground water from floating the tank. Close-grained cast iron body and lid; lead seat ring and lid ring. Cast iron grate in bottom prevents foreign matter from entering tank.

IOWA PLUG DRAIN VALVES—either rising or non-rising stem type. High strength cast iron bodies; bronze stem, operating nut, disc ring and seat ring; rustproof steel bolts and nuts. Handwheels, extension stems, plain or indicating floor stands if required.

IOWA SLUICE GATES—can be used in lines having both seating and unseating pressures. High strength cast iron, bronze mounted, with solid bronze adjustable wedges. Can be equipped with cylinder or motor unit for automatic operation.

IOWA SHEAR GATES—either all iron or iron, bronze mounted. Gate-seating wedges bolted on, permitting replacement without replacing frame.

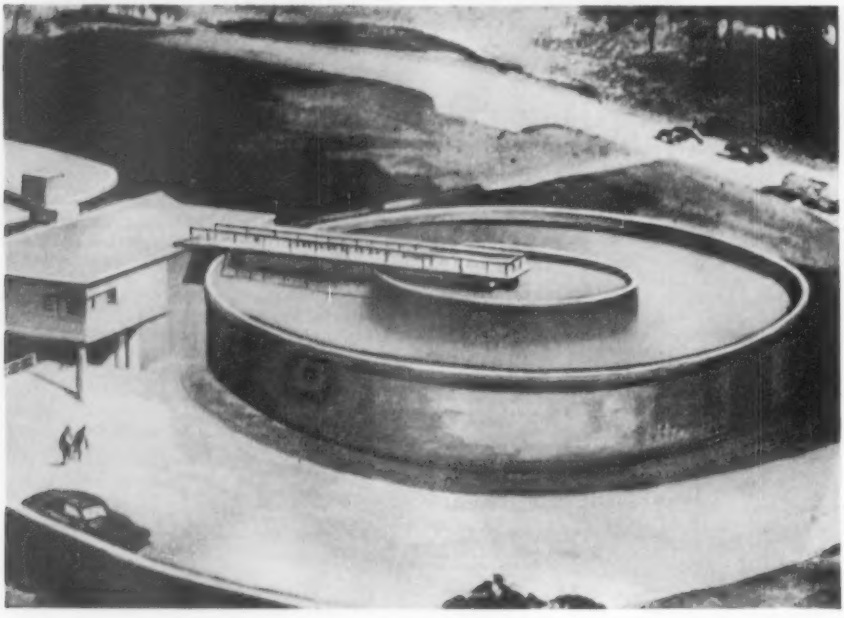
For 45 years a reliable source for **precision engineered products**

IOWA VALVE COMPANY

A Subsidiary of James B. Clow & Sons

Oskaloosa, Iowa

AERO-ACCELATOR (Trade Mark) Treatment Plants provide complete sewage treatment at lower cost!



The "AERO-ACCELATOR" treatment units provide high rate sewage treatment (overall BOD reduction better than 90%) at *low cost*. Embodying the latest concepts of activated sludge processing and solids separation, this compact unit requires a detention time of only 4 hours at average flow for complete secondary treatment. This means important savings for any community or institution, regardless of plant capacity.

If you are planning a sewage plant, see your consulting engineer or write INFILCO regarding the economical "AERO-ACCELATOR" treatment unit.

NEW ROTAGRATOR® screen and comminutor

A revolutionary development for screening and comminuting *all* coarse sewage material without rejection or removal from the flow. Reduced head loss, straight-channel installation and low power requirement. Eliminates odor and handling nuisances.

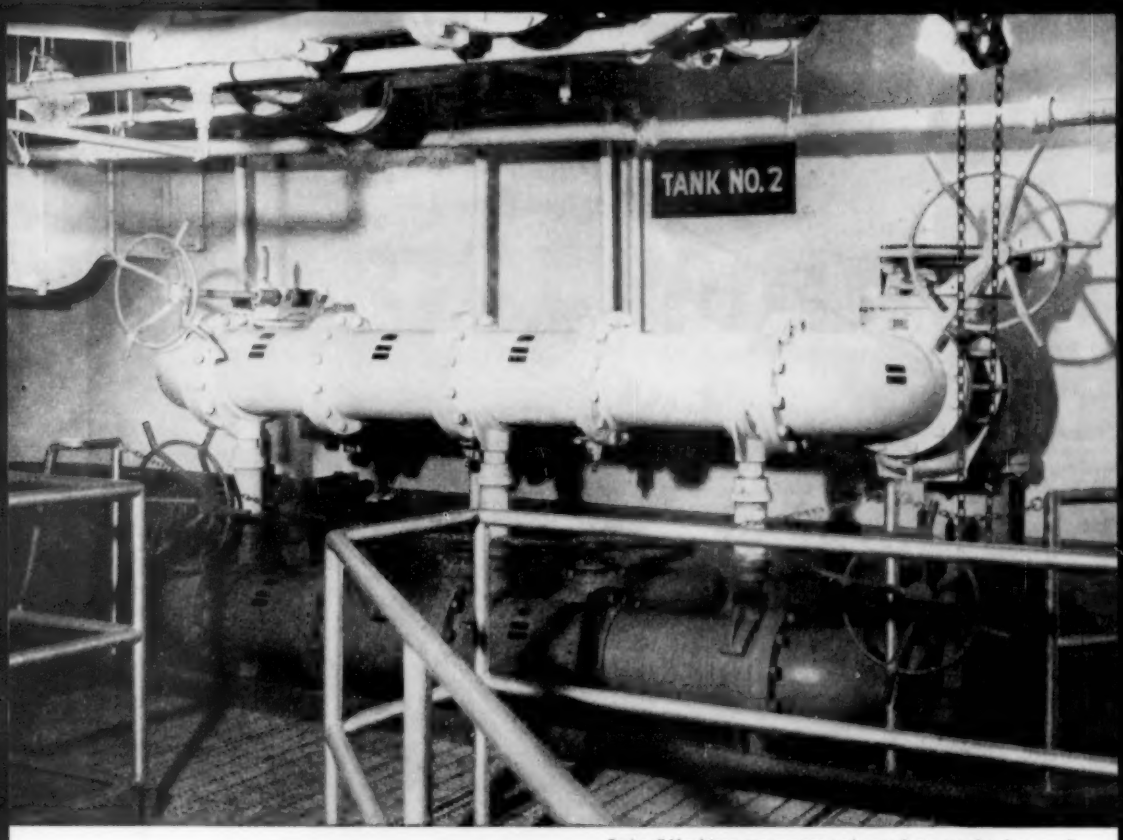
INFILCO INC.

921 South Campbell Ave., Tucson, Arizona

Field offices in principal cities in North America 5031

INFILCO

The one company offering engineered equipment for all types of water and waste processing—coagulation, precipitation, sedimentation, flotation, filtration, ion exchange and biological treatment.



Rockwell-Nordstrom worm gear and wrench operated valves on digester recirculating sludge lines assure low cost, efficient control.

Costs Down....Efficiency Up

with Rockwell-Nordstrom Valves for sludge and digester service

For *any* service from water to treatment chemicals, *tapered* plug design plus pressurized lubrication decreases maintenance cost and assures trouble-free operation in three important ways:

1 Costly down time for stuck valves is eliminated because the *tapered* plug in Rockwell-Nordstrom valves is hydraulically cushioned for *instant* operation.

2 Pressurized lubricant film between the plug and the valve body dependably seals against *costly or annoying* leakage of the lightest gases of heaviest slurries.

3 Metal-to-metal wearing friction is eliminated and working surfaces are protected by the tough lubricant film . . . repair and replacement costs are slashed.

It will pay you to standardize on Rockwell-Nordstrom, the *original* and complete line of lubricated plug valves. No matter what your requirements, there is a Rockwell-Nordstrom valve (and a complete selection of valve accessories) that will do the job with more trouble-free dependability and at lower cost than any other valve you've used. Send the coupon today for Rockwell's new, free book on Rockwell products for sewage and wastes services and learn how you can cut your costs with Rockwell meters and regulators and Rockwell-Nordstrom valves.

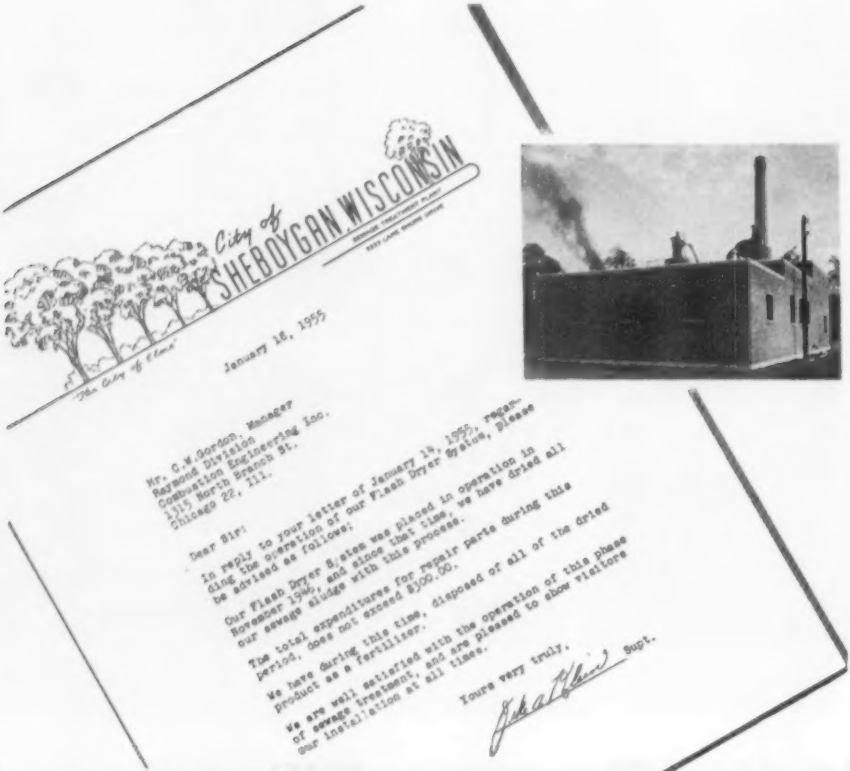
ROCKWELL-Nordstrom **VALVES**
Lubricant Sealed For Positive Shut-Off

Canadian Valve Licensee: Peacock Brothers Limited

Rockwell Manufacturing Company DEPT. 7
Pittsburgh 8, Pa.

☐ Please send me, free, Bulletin C-5200.
☐ Please have your representative call.

Name _____ Title _____
Company _____
Street _____
City _____ Zone _____ State _____


City of
SHEBOYGAN, WISCONSIN
January 16, 1955
Mr. C.W Gordon, Manager
Raymond Division
Combustion Engineering Inc.
1315 North Branch St.
Chicago 22, Ill.
Dear Sir:
In reply to your letter of January 14, 1955, regarding the operation of our Flash Dryer System, please be advised as follows:
Our Flash Dryer System was placed in operation in November 1945, and since that time, we have dried all our sewage sludge with this process.
The total expenditures for repair parts during this period, does not exceed $300.00.
We have during this time, disposed of all of the dried product as a fertilizer.
We are well satisfied with the operation of this phase of sewage treatment, and are pleased to show visitors our installation at all times.
Yours very truly,
Supt.

Just mention our name in Sheboygan

Mention it at any rate to Jake Klein, Superintendent of the Sewage Treatment Plant, and he will be glad to show you around. He knows us and our equipment. In fact, for almost ten years the Sheboygan plant has been flash drying its digested sewage sludge with C-E Raymond Flash Drying equipment — and *selling its entire output.* During the past year, the total production of the plant amounted to 905 tons.

Naturally, we're pleased as Punch with Jake's letter reprinted here — but hasten to add we've received many others.

So, if you're thinking of a new disposal plant, investigate the C-E Raymond Flash Drying System. It can incinerate—or dry—or both—alternately or concurrently. We believe we have the best system of sewage sludge disposal. We would like the opportunity to tell you why. B-634-A

COMBUSTION ENGINEERING

RAYMOND DIVISION

1315 North Branch Street, Chicago 22, Illinois

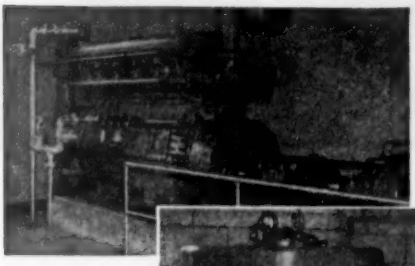
Eastern Office: 200 Madison Ave., New York 16, N. Y. Western Office: 510 West Sixth St., Los Angeles 14, Calif.

ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL

Long-wearing

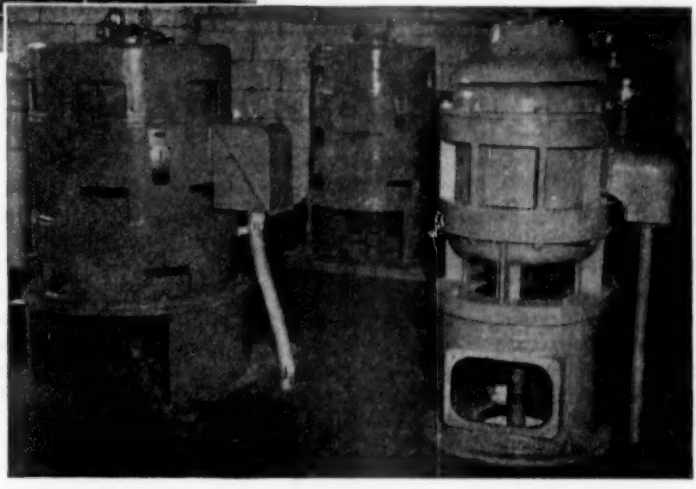
INERTOL® PAINTS

specified in Elmira, New York, plant



Sparkling protection was afforded this big gas engine at Elmira's Sewage Treatment Plant with Inertol Glamortex® Enamel. All surfaces were first primed with Inertol Quick-Drying Primer No. 626, a top-quality rust inhibitor which provides a perfect bond for the finish coats.

Easy maintenance of this battery of sludge pump motors was achieved with Glamortex Enamel, Battleship Grey No. 331. This easy-to-clean paint stands up for years under abrasion, oil spillage and frequent cleaning.



Inertol Paints meet precise requirement of plant designed by Nussbaumer, Clarke & Velzy

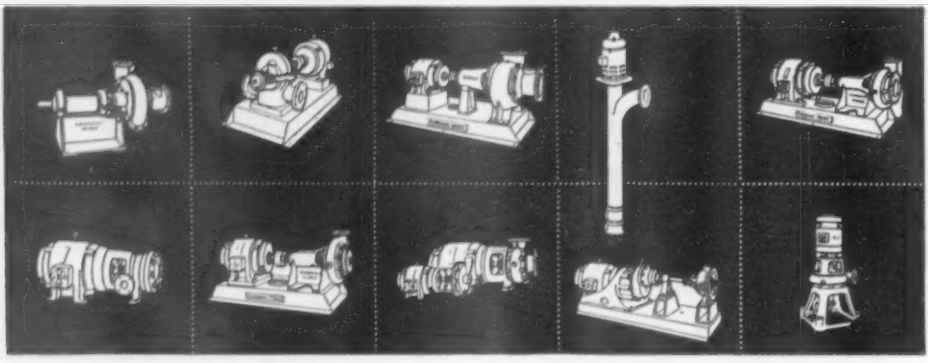
For top protection, Elmira's Sewage Treatment Plant needed paints that would provide lasting durability, elasticity and chemical resistance. That's why Inertol coatings were chosen for this modern plant which was designed and constructed under the supervision of Nussbaumer, Clarke & Velzy. Inertol meets all these exacting requirements. For 18 years, the city of Elmira has been using hundreds of gallons of Inertol Paints—bituminous coatings as well as colored enamels.

All over America, thousands of Inertol-painted installations speak for this paint's economical and efficient superiority. Whatever your specific painting problem is, there's sure to be an Inertol coating to solve it. Ask to have your local Inertol Field Technician call. Or write for our free "Painting Guide." It's prepared especially for Consulting Engineers, Specification Writers, Design Engineers and Plant Superintendents. Send for this valuable booklet today.

INERTOL CO., INC.

482 Frelinghuysen Ave.
Newark 5, N. J.

27H South Park
San Francisco 7, Calif.



YOU CAN RELY ON YOUR F-M PUMP ENGINEER...

to solve any pump problem!

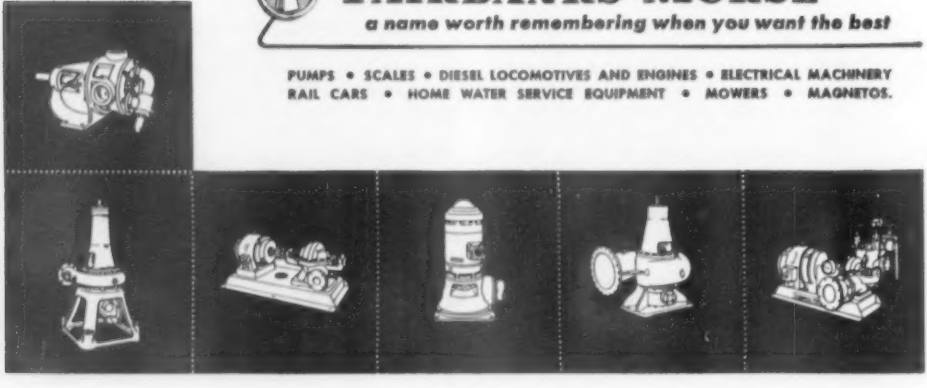
Troubled by a pumping problem? There's an easy solution. Call your Fairbanks-Morse Field Engineer. His business is solving your problems . . . selecting and applying pumps that will answer your needs most economically and efficiently.

Because Fairbanks-Morse is the world's largest manufacturer of a complete pump line, your Fairbanks-Morse Field Engineer is not handicapped in his recommendations. He can select the pumps that offer you the most for your pump dollar. He has the field experience and is backed by the most experienced pump engineering department in the business. To solve your pump problems, call your Fairbanks-Morse Field Engineer. Fairbanks, Morse & Co., Pump Div., 3601 Kansas Ave., Kansas City, Kan.

FAIRBANKS-MORSE

a name worth remembering when you want the best

PUMPS • SCALES • DIESEL LOCOMOTIVES AND ENGINES • ELECTRICAL MACHINERY
RAIL CARS • HOME WATER SERVICE EQUIPMENT • MOWERS • MAGNETOS.



BEFORE YOU PLAN your sewer system it will pay you to consider carefully all the advantages listed on this page. They are typical of those that Transite® Sewer Pipe has provided. Among them are real money-saving advantages important to all concerned with sewer systems . . . the contractor, the engineer, the taxpayer. And among them, in all likelihood, are many that Transite Pipe can put into effect *under your own sewer system conditions.*

Typical System Design Advantages

- Installed in shallower trenches
- Savings in amount of material excavated
- Smaller earth loads
- Elimination of cradling
- Location of treatment plant at higher level
- Elimination of pumping
- Use of smaller diameter pipe
- Installation at flatter slopes

Typical Installation Advantages

- Fewer joints
- Easier handling
- Smaller crews
- Speedier assembly
- Assurance that joints pass severe infiltration tests

Typical Operation Advantages

- Infiltration treatment cost drastically reduced
- Only normal sewage treated

Typical Maintenance Advantages

- Tree roots kept out—minimizes cleaning
- Sewers kept smooth and intact—pipe stays strong, joints stay resilient
- Need for frequent inspections reduced

For further information and your copy of TR-94A, helpful, widely used Sewer Design Flow Chart based on the Manning Formula, write Johns-Manville, Box 60, New York 16, New York

Johns-Manville TRANSITE SEWER PIPE
the asbestos-cement sewer pipe for tighter systems

Plan with Quality...

Pekrul

4-36" Pekrul model 45A Sluice gates at Sacramento Sewage Treatment plant

City managers...engineers... contractors...know that the precision engineering and quality construction of Pekrul Gates means a *planned* water control project that will fulfill its purpose. It costs no more to plan with quality...specify **Pekrul Gates** on your next project.

PEKRUL GATE DIVISION

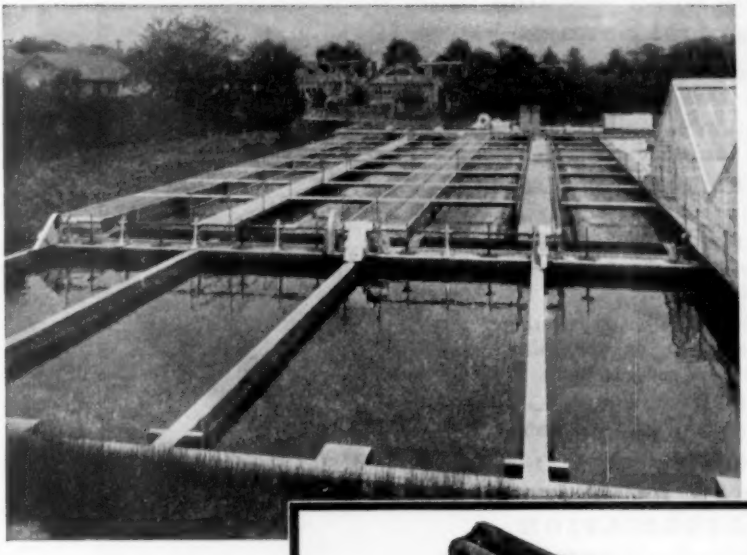
Write on your letterhead for NEW Pekrul Gate Catalog No. 55

MORSE BROS. MACHINERY
DENVER, COLORADO

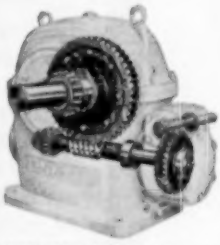
MANUFACTURERS OF PEKRUL GATES FOR

Flood Control · Sewage Disposal · Rearing Ponds · Recreation Pools
Levees · Reservoirs · Irrigation · Cooling Towers · Pumping Plants
Water Works · Oil Refineries · Steel Mills · Dams · Fish Hatcheries

How will your judgment on SANITARY ENGINEERING EQUIPMENT look after 15 years?



FOR 15 YEARS, the Link-Belt chain on final tank Straightline Collectors at this Collingswood (N.J.) activated sludge plant rendered dependable service, running 24 hours per day, *without replacement.* Straightline collectors in primary tanks have been in service for 24 years without replacement. Clearness of effluent may be judged by reflection of the drive machinery in final tanks in foreground.



ENCLOSED DRIVES. All types have sturdy gray iron housings, anti-friction bearings and precision gears for long trouble-free operation.

CHAIN. Made of Promal, the longer-wearing pearlitic malleable iron, has toughness, strength, high yield point, high resistance to abrasion.

SPROCKETS. Flint-Rim wheels have smooth, file hard, wear-resisting teeth, assuring maximum life.

LINK-BELT equipment is sturdily designed to last for decades

REMEMBER this when developing specifications and interpreting quotations on your water, sewage or industrial waste treatment system. It pays to give thoughtful analysis to design and equipment which will assure long life with little maintenance. Such scrutiny will also tell you why — in cities large and small . . . in plants of all types — Link-Belt installations continue to deliver top efficiency at lowest operating cost for many years.

Link-Belt offers you a broad line of *quality* sanitary equipment — including screens, collectors, mixers and complete conveying and power transmission equipment. In fact, Link-Belt pioneered such life-lengthening features as Flint-Rim sprockets and Promal chain.

With this wide choice of equipment, you also put Link-Belt's many years of technical experience to work on your needs. These two are your assurance of sturdy design . . . close attention to all construction details . . . a thoroughly tested, tried and proved system.

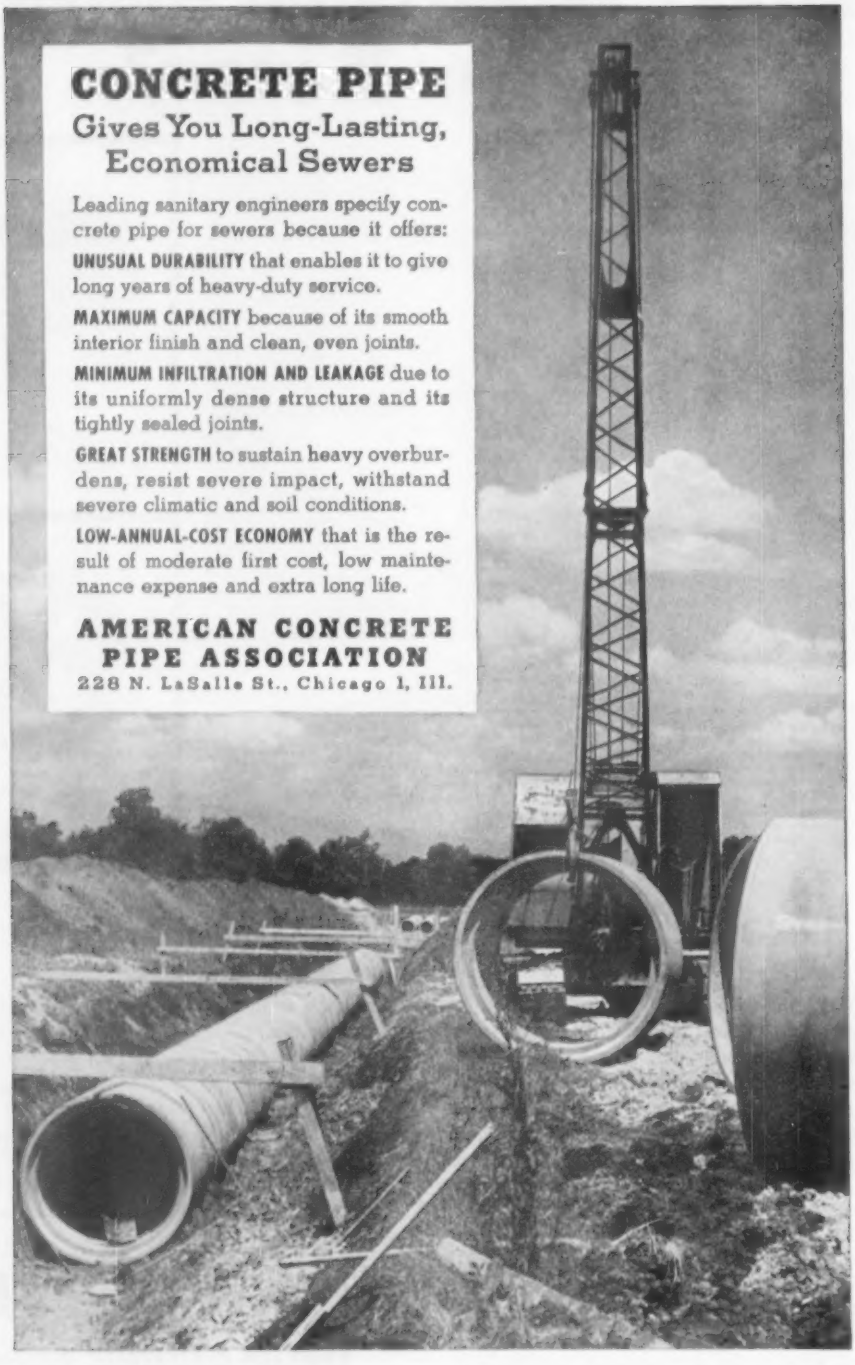
Next time you're faced with water, sewage or industrial waste treatment problems, call your nearest Link-Belt office. Our engineers will work with yours . . . with your chemists and consultants to provide you with the finest in modern treatment equipment.

LINK-BELT

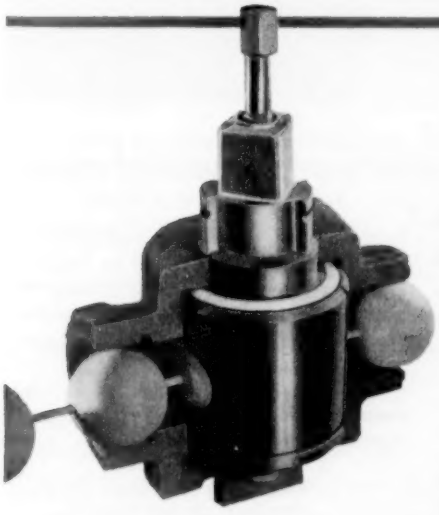
SANITARY ENGINEERING EQUIPMENT

LINK-BELT COMPANY: Executive Offices, 307 N. Michigan Ave., Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World.

13,827


CONCRETE PIPE
Gives You Long-Lasting, Economical Sewers
Leading sanitary engineers specify concrete pipe for sewers because it offers:
UNUSUAL DURABILITY that enables it to give long years of heavy-duty service.
MAXIMUM CAPACITY because of its smooth interior finish and clean, even joints.
MINIMUM INFILTRATION AND LEAKAGE due to its uniformly dense structure and its tightly sealed joints.
GREAT STRENGTH to sustain heavy overburdens, resist severe impact, withstand severe climatic and soil conditions.
LOW-ANNUAL-COST ECONOMY that is the result of moderate first cost, low maintenance expense and extra long life.
AMERICAN CONCRETE PIPE ASSOCIATION
228 N. LaSalle St., Chicago 1, Ill.

ROUND HOLES *FOR* ROUND PEGS

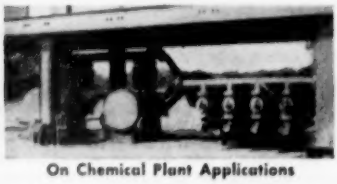


That's an elementary lesson. And that's one of the big advantages of **a c f** Cylindrical Round Port Valves. Because they are the exact size and shape of the pipe itself...they assure smooth, unrestricted flow of the most heavy viscous ladings. No obstructions. No loss in head pressure. No turbulence and harmful abrasive effects from solids in suspension. Just the utmost in flow perfection!

Remember, too, *both* **a c f** Round Port Valves and Rectangular Port Valves feature quarter-turn shut-off ... full pipe area opening ... and non-wedging design. All together ... these advantages add up to extra long, trouble-free service life that really *s-t-r-e-t-c-h-e-s* your maintenance budget. Representatives in 50 Principal Cities. Write for descriptive Catalog 6-SI, **a c f** Industries, Incorporated, Valve Division, 1501 E. Ferry Avenue, Detroit 11, Michigan.

Proved Best on Raw Sewage Lines

In the Petroleum Industry



On Chemical Plant Applications

acf CYLINDRICAL PLUG VALVES

Rochester's two 50′ digesters, each equipped with PFT Floating Cover

At Rochester, Minnesota . . .

Modern sewage treatment for world's medical center

EXPANDABLE NEW PLANT INCLUDES PFT "CONTROLLED DIGESTION"

Looking far into the future, Rochester has built a trickling filter plant designed to grow with the city for the next 60 years! Completed in 1952, plans already call for additions that will handle 7 MGD by the year 2000 . . . nearly *twice* its present load. PFT equipment was installed in the plant for effective "controlled digestion."

A PFT Floating Cover is installed in each of the 50′ digesters for accelerated digestion and positive scum submergence. Operations are simplified because additions and withdrawals can be made at times best suited to the overall operation . . . no fixed levels need be maintained.

Breakdowns and repairs are materially reduced because the Floating Covers contain no moving parts. Since no mechanical agitation is required, and heat is supplied from *external* heaters, all maintenance takes place outside the tank.

In the Control Room, a *PFT Heater & Heat Exchanger unit* (500,000 B.t.u. per hr.) maintains close temperature control of the digesters *automatically*. Fired by digester or city gas, it cuts fuel costs by utilizing all gas produced in the digesters. Effective "controlled digestion" is due in large part to this automatic heat control!

Congratulations to Rochester, medical center of the world, on its excellent new plant and its far-sighted planning!

Design of plant by / *Toltz, King & Day, Inc. St. Paul, Minnesota*

Superintendent Walter C. Hogenson checks heat output of PFT Heater & Heat Exchanger unit in the digester control building.

P.F.T.

waste treatment equipment exclusively since 1893

PACIFIC FLUSH TANK CO.

4241 Ravenswood Avenue
Chicago 13, Illinois

PORT CHESTER, N. Y. • SAN MATEO, CALIF. • CHARLOTTE, N. C. • JACKSONVILLE • DENVER

SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 27 | **June, 1955** | **Number 6**

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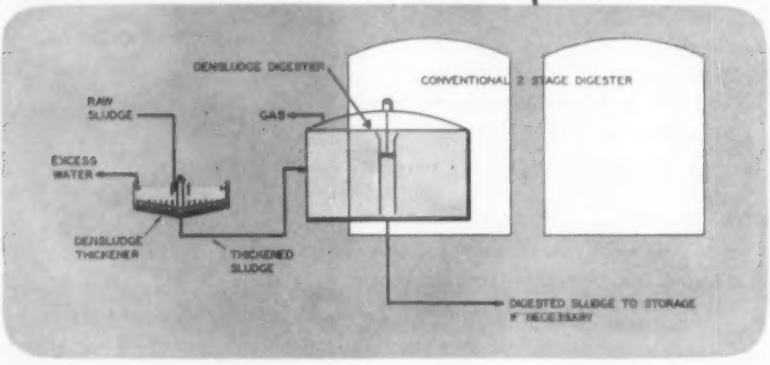
Densludge System Cuts Digester Requirements up to 80%



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1954 Literature Review

A CRITICAL REVIEW OF THE LITERATURE OF 1954 ON SEWAGE, WASTE TREATMENT, AND WATER POLLUTION

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Committee on Research, Section A, Federation of Sewage and Industrial Wastes Associations

This is the second of two sections of the review. The first section, dealing with analytical methods, sewage, and radioactivity, was published in the May, 1955, issue of This Journal.

INDUSTRIAL WASTES

Cannery

Treatment

Wakefield (242) reported promising results of research on treatment of citrus wastes by trickling filtration, activated sludge aeration, and irrigation. Flotation was suggested for collection of secondary sludge. Irrigation was considered attractive where suitable land and acid-resistant cover crops were available. McKinney *et al.* (137) described laboratory studies of activated sludge treatment of citrus peel bin liquor using sludge with nitrogen-fixing properties to overcome nutritional deficiencies. McNary *et al.* (138) found citrus peel oils retarded digestion of citrus wastes. Digestion was still not feasible after oil removal by aeration because of unsolved problems of supernatant separation and sludge recycle. Two cases of odors arising from citrus waste disposal were presented (15). One resulted from discharge of partially treated wastes to a lake receiving municipal plant primary effluent. The other resulted from interaction of wastes with warm cooling waters containing 600 p.p.m. sulfates, which were reduced to sulfides.

Tetsch (230) discussed wastes from preparation of smoked and marinated fish products. The only treatment practiced was grease removal. A grinder was described (16) for shredding solid food wastes to $\frac{1}{16}$ in. particles at rate of 1,000 lb. per hour. The unit uses 10 g.p.m. of water to flush the ground solids.

Miller (145) reported on spray irrigation disposal of vegetable canning wastes. Screened wastes are distributed through movable pipe sections and applied to a 240-acre plot at the rate of 1.3 m.g.d. Powell (178) dis-

cussed Canadian spray irrigation practice for disposal of canning wastes. Webster (246) and Mather (130) reviewed several years experience in forest and field spray irrigation disposal of 10 m.g.d. of vegetable processing wastes. Factors discussed include soil type and erosion, effect on vegetation and soil permeability, and ground-water recharge rates. The wooded area receives 20016 B.O.D. per acre-day and 400 to 600 in. of water depth in an 8-month period. Monson (147) presented operating experience at five plants successfully disposing of vegetable wastes by spray and ridge-and-furrow irrigation.

Dickinson (55) discussed year-round operation of a trickling filter plant at a medium-sized fruit and vegetable cannery in England. Ingols *et al.* (96) reported solution of a peach canning waste disposal problem by use of vibrating screens and nitrate addition to a lagoon. Waste volume reduction at pea canneries was discussed by Mercer and York (142). Chlorination to 0.1 to 0.5 p.p.m. residual permits water re-use for fluming and reduces thermophilic spore counts. A Michigan pea cannery (8) uses a 50-mesh 48-in. vibrating screen to treat 10,000 g.p.h. with resultant removal of 400 to 600 lb. of solids per hour. Ambrose and Reiser (3) surveyed wastes from five potato starch plants. Wasted pulp accounts for 43 per cent of the B.O.D. load, while 52 per cent results from discharge of protein wash water. The load equals 350 population equivalent per ton of potatoes. The average plant processes 240 tons per day with a load equal to a population equivalent of 85,000. Ammerman and Destrosier (4) found aeration superior to either nitrate or *o*-dichlorobenzene for odor control in tomato waste lagoons.

Recovery

Von Loesecke (240) reviewed by-product recovery from citrus wastes. Products mentioned include dried pulp, molasses, feed yeast and alcohol. Peel by-products include peel oil and pectin. Oil is recovered from seeds, using conventional expeller-type presses. Buswell and Boruff (36) patented a process for yeast production followed by methane fermentation of residual citrus waste liquors. Gaden *et al.* (71) studied citric acid and riboflavin production by fermentation of citrus molasses. Riboflavin yields using *E. ashbyii* suggest a possible method of upgrading molasses as an animal feed supplement.

Tada and Nakayama (222) suggested mixing fish wastes with molasses or sweet potatoes and fermentation with yeast or bacteria to produce animal feed. Neubert *et al.* (163) described a method for sugar recovery from pear canning waste solids by means of pectate gel pressing followed by purification. The recovered sugar syrup can be re-used in canning and the pomace dried for animal feed. Cost data for the process are presented. Graham *et al.* (80) patented a process for conversion of solid pear wastes to animal feed. Adams (1) described promising results of research on yeast fermentation of various fruit canning wastes. Reiser (182) reported a laboratory study of Torula yeast production from potato starch waste protein wash water. Yeast containing 55 per cent protein was produced with 60 per cent B.O.D. reduction. Cost estimates for a plant processing 240 tons per day of potatoes indicate a yeast cost of $0.05 per lb. using Waldhof-type equipment. Blending of yeast with dried potato starch pulp waste and corn produced a well-balanced chicken feed.

Corn and Sugar Processing

Rogers and Smith (185) describe the use of lagoons to store beet sugar manufacturing wastes during the producing period of the year. The waste is admitted to the stream on a year-round basis or when the flow is adequate to

prevent damage. The lagoons are covered with ice for the producing season so that no reduction in the B.O.D. occurs except from settling. Votava (241) reports that two beet sugar plants in Czechoslovakia use lagoons for waste treatment. The effluent from the ponds is re-used in the plant, the pH being adjusted at the end of the season so that self-purification takes place during the summer when the plants are not in use. One of the by-products frequently obtained from beet sugar manufacture is monosodium glutamate (MSG); however, the wastes from the production of the MSG are also a major problem according to Pearson, Weinberg, and Whitsell (169), who indicate that thermophilic anaerobic digestion may be the answer to the manufacturing wastes from the MSG. Loadings of 0.1 lb. per cu. ft. per day may be possible if the NaCl concentration does not get too high.

Dairy Wastes

The U. S. Public Health Service (236) has issued an "Industrial Waste Guide to the Milk Processing Industry" (prepared by the Dairy Industry Committee's Subcommittee on Dairy Waste Disposal). It is concise and probably is an improvement over the guides previously issued by the Dairy Industry Committee and the Pennsylvania Association of Milk Dealers. All of these guides put great stress on waste saving. This new guide gives operating data for six dairy waste aeration plants.

Southgate (213) reviews available methods of dairy waste disposal. Under British conditions better effluents are required than under American conditions; consequently, in England the trend is toward the use of alternating double trickling filters, whereas in the U. S. the trend is more toward high-rate trickling filters and high-rate sludge return activated sludge plants.

Stander (216) reviews the dairy waste disposal methods used mostly in the United States and England. Nothing new is presented and the information is somewhat out of date. With some changed wording, this review was used for a conference paper (215) with no references.

McKee (136) points out three trends in the dairy industry that are helpful in getting better waste saving; namely, (a) longer drip savers of sanitary construction ahead of can washers, (b) permanent pipelines cleaned in place instead of the usual demountable pipelines, and (c) bulk milk pickup on the farm instead of handling in 10-gal. cans.

Rapp and Calbert (180) present new data on the relation of stickage losses of milk to the rate of dumping. Losses were about 0.2 per cent of the milk dumped at a rate of 5 cans per minute and rose to 0.4 to 0.7 per cent at 10 cans per min. The fat test of the drainage milk was about 1.9 per cent fat higher than of the milk dumped. These data confirm previous data reported by Schwarzkopf in 1951.

Shuttleworth (205) presents a review and summary of all work then known (mostly from U. S.) on the utilization of whey and buttermilk.

Genin (77) stresses the importance of by-products utilization alleviating the waste disposal problem, but has nothing new to contribute. In this connection it is interesting to read Sprague's (214) report on whey. He explains why whey concentrates and whey powders have been replaced by the corresponding skim milk products and that there is little hope of finding increased uses for whey products before the entire milk solids surplus situation has been straightened out. The production of yeast or yeast-containing feed products from whey has been discussed from time to time by various authors, but whey has difficulty in competing with other cheap raw materials in this field.

Botha (28) gives detailed and well-organized recommendations for waste

savings, which are similar to those of American dairy industry waste committees. In a later paper (29) he reports on the dairy waste disposal situation in South Africa and stresses waste saving and the need for by-products utilization. Whey is being used mostly for pig feeding. He describes waste disposal by broad irrigation (not spray) for 15 years by one plant that has 5,000 g.p.d. (Imp.) of waste. A fat trap is used ahead of the irrigation field, which consists of 1½ acres of land split in 22 strips, each about 15 ft. wide by 100 ft. long. A temporary gutter is laid along the middle of the strip and a 10-ft. length of gutter is moved at a time to the next strip.

He also discusses the use of trickling filters. As in England, two filters are used in series with a settling tank between them and are preceded by a fat trap and a flow equalizing tank. For best results the order of the trickling filters is alternated every few days. The above-ground filter consists of stone of 1-in. to 4-in. size, 6 ft. deep. The loading is 100 to 200 g.p.d. (Imp.) per cu. yd.

Jasewicsz, Porges and Hoover (97) report on the usefulness of borax at 2 per cent concentration as a preservative for samples of dairy waste for the C.O.D. test and the B.O.D. test as long as the B.O.D. dilution contains less than 1,000 p.p.m. borax.

The same authors (90) also report in detail the technic of using the magnetic oxygen analyzer in studies of oxygen uptake by synthetic dairy waste inoculated with a biological sludge. The results were discussed last year.

Kountz (115) made a preliminary report on the design and operation of a pilot plant for dairy waste treatment based on laboratory data of Hoover and co-workers (reported in previous years). This is a fill and draw, activated sludge type operation which has given encouraging results although no analytical data from complete daily sampling in proportion to flow of influent and effluent have as yet been published. The claim of complete aerobic digestion of excess sludge is interesting and presumably will also be supported by careful analytical work to be published later.

Kountz (113) (114) also reported briefly on two commercial installations of the same type of fill and draw operation, using eductors sucking air from the atmosphere instead of supplied with air under pressure. Again the claim is made that a sludge volume equilibrium is reached and maintains itself automatically by endogenous oxidation of the cells and consequently no means for disposal of excess sludge are required with this method of operation as long as there is an adequate supply of oxygen. Serious frothing problems have been encountered and are attributed to excess air.

Schulze (199) reports on an activated sludge type of operation using 2-stage mechanical aeration adapted from the type of equipment used in the yeast industry. He reports 98 per cent B.O.D. reduction in 15.4 hr. of aeration. The air is sucked in through the hollow shafts of the mechanical aerators at a rate of 14 c.f.m. for the two aerators together, or 208 to 485 cu. ft. per pound of B.O.D. Excess sludge is removed daily to drying beds. Power requirements appear to be fairly high since the two aerators together, using 6 hp., remove only 87 lb. of B.O.D. (90 per cent removal). A funnel-top cylinder is placed in such a way that froth from the top of the tanks is sucked down by the impellers.

From all the studies of activated sludge treatment of dairy waste it is becoming increasingly clear that the secret of economical and fool-proof treatment (of strong organic wastes, such as dairy waste) depends largely on the development of low-cost, high-capacity, reliable aeration devices that give maximum oxidation per horse-

power-hour. A review by Finn (70) of the literature on agitation-aeration is of particular interest.

Wittmann (254) describes a large recirculating trickling filter installation (about 90 ft. diameter by 10 ft. deep) in Germany showing a B.O.D. reduction of better than 98 per cent with relatively low loadings.

Two papers by Pien (173) (174) appear to be based largely on earlier work. He continues to stress self-purification in streams and recommends a double fermentation process, first to remove lactose and then protein, followed by filtration over a peat bed, a seemingly complicated process.

Coin and Mathys (42) show data on the variations of pH and oxidation-reduction potential as a result of aerobic and anaerobic incubation of effluents from a dairy, a sugar refinery, and a yeast factory.

Tregubov (232) gives partial chemical and bacterial analyses of silt and water from two ponds and two rivers in the Ukraine contaminated with butter factory waste liquids.

Papers by Keiling (103), Muers (148), and Camus *et al.* (39) are all reprints of papers given in 1952 at the World's Dairy Congress and reviewed in 1953.

Certain data from Schaafsma's 1953 paper on the volume and nitrogen content of wastes from cheese, butter, and milk products plants, and on the effect of waste savings efforts, are available in English (193).

A report from the Danish Experiment Station (51) summarizes recommendations for spray irrigation of dairy waste. Under Danish conditions the best utilization of the land is obtained if the amount sprayed during the seven-month season does not exceed what corresponds to 300 mm. of rainfall. The diameter of the spray should be such that the amount of waste water sprayed daily does not exceed 15 to 20 mm. For instance, 13,000 g.p.d. of waste would require a spray covering about 30,000 sq. ft., or a diameter of about 200 ft. The spray is moved once a day. The holding tank must be emptied every day and the spray nozzle must be kept clean. Grassland is better than bare bround. The porosity of the soil is of no particular importance. Apparently the recommended rate of application of waste water in Denmark is much lower than in the United States.

Haack (81) discusses the possibility of transmission of tuberculosis in cattle by spray irrigation of dairy waste waters. His conclusion is not definite, but he does point out that under certain conditions it may be possible for tuberculosis organisms to survive on grass and be transmitted to animals on pasture.

Packinghouse Wastes

A new edition of USPHS "Industrial Waste Guide to the Meat Industry" (237) incorporates experiences of packinghouses over the 10-year period since the first edition was printed.

The paper on anaerobic digestion of packinghouse wastes reviewed last year has been reprinted by Shroepfer (196).

Straub (219) has presented a careful evaluation of the data published concerning packinghouse wastes and indicates the importance of including values that are necessary for an adequate statistical study of the data.

Fermentation Industries

Because of the very strong wastes produced by the disposal of spent beers from the fermentation industry, there is a tendency toward disposing of them by other means than in the waste water. Edmundson (65) indicates that spent antibiotic beers can be disposed of more economically by triple-effect evaporation, including the cost of hauling the concentrate from the plant, than by inclusion of the beer in the waste stream for biological treatment. The evaporators are cheaper to build and operate.

Where the wastes from antibiotics manufacture are treated on trickling filters, Kaufman (101) has found that large variations occur in the degree of treatment obtained during different seasons of the year, the organic matter in the waste being more easily treated during warm weather than during cold weather. This change in efficiency is attributed to the toxic effect of the residual antibiotics. Reimers, Rinaca and Poese (181) indicate that other plants having spent beers have found it necessary to concentrate and incinerate their strong wastes while treating their weak wastes with sanitary engineering devices. Gallagher *et al.* (72) indicate that spent broth can be treated on trickling filters when the broth is released at a controlled rate. Even spoiled batches and wastes containing solvents are discharged to waste at a controlled rate so that the filters can maintain their effectiveness. Automatic pH control devices maintain a desirable condition of the waste received at the filter.

The various biological methods for treating waste waters from distilleries are described by Wittmann (253). The strength of the waste waters from distilleries is compared with similar industries in terms of population equivalents.

Chemical Wastes

Several extensive surveys of chemical wastes were reported during 1954. The Manufacturing Chemists Association (143) has made available in manual form directions for the neutralization of acidic and alkaline wastes. The current literature has been well summarized, although no citations are given. Wilson (251) presents the waste handling experiences of Monsanto's plant in Scotland. The industry has maintained pilot plants for continuing study and has found the use of nutrients from a nearby sewage plant helpful. On the other hand, Hill (88) has surveyed the many chemical engineering processes that are available for application to waste treatment problems. He emphasized the possibilities of extraction and adsorption.

Two articles deal with the problem of wastes from the production of phosphate-rich rock where the fines are at present wasted. Thompson and Vilbrandt (231) have studied the use of ultrasonic sound energy upon the dewatering of the slurry obtained from the ponds used to remove the fine phosphate rock washings from the plant waste water discharge. The fine particles have not compacted well and a technique of increasing the phosphate yield at reasonable cost was reported. Tyler and Waggaman (234) gave a complete review of the problem, with a discussion of many possible methods for reducing the present lagoon area and for gaining a sizeable phosphorus supply without further mining.

Heller and Wenger (85) describe the changes in the plant processing which removed all phenol from the waste stream. This approach has resulted in the recovery of all of the cost of plant changes in the greater yield of phenol.

Because of the highly dangerous character of cyanides, the methods for treating these wastes have been described frequently. Walker (244) indicates that the cyanides from a silverware factory are oxidized with chlorine, the silver being converted thereby to the chloride, which can be recovered. Other heavy metals are precipitated by pH adjustment and the effluent from all treatment processes is mixed and filtered. Brink (32) discusses fully the precautions used in handling cyanide baths before treatment and the plant layout for destroying the cyanides with chlorine. It costs $0.75 per pound of cyanides in the waste to obtain a satisfactory effluent. Couch (46) indicates that cyanides will be treated in a separate batch system as part of a large treatment plant for many wastes. Batch units will be used for treating chromium, acid, and al-

kaline wastes. A final mixing with clarification at this stage will be used before discharge.

A rather novel method (10) of getting sulfides out of a sulfur mining waste was obtained by treating the water with sulfur dioxide. The oxidized and reduced form of sulfur reacted to produce free sulfur, which can be settled out. Optical rouge wastes present a serious problem in the appearance of the receiving stream, according to McCarthy (134), who recommends use of calcium chloride for coagulation of the suspended iron oxide and glass.

Kline and Fletcher (108) describe the program used for scheduling the discharge of chemical wastes into a river so that no treatment is needed, provided no two batch discharges into the receiving stream occur simultaneously.

Edwards and Ingram (66) report that the color of TNT wastes can be reduced by chlorination with gas in a countercurrent packed tower. The red wastes become yellow, which causes much less disturbance to the appearance of the stream.

Oliver (165) describes a plant for destroying 16 tons of B.O.D. per day from organic matter which is waste from the manufacture of ethylene glycol. One waste has 15 per cent organic matter, which is heated by the exhaust gases from a catalytic burner. The air is preheated to start up the process, but the waste contains enough combustible matter to make the process self-sustaining.

Majewski (123) reports on the techniques for handling the various acid wastes from an organic chemicals producing plant. Sulfuric acid contains tars which are removed after neutralization with ammonium hydroxide. The ammonium sulfate is then recovered for sale as fertilizer. Phosphoric acid is neutralized for salts to be included in fertilizer or detergents. Hydrochloric acid is neutralized with granular high-calcium limestone in beds. Liontas (119) describes the results of trickling filter treatment of the highly variable wastes from a plant producing antibiotics and synthetics drugs.

Textile Wastes

Gerstner (78) reports on the recovery of copper from cuprammonium rayon spinning wastes by use of ion exchange. By the method copper is precipitated from the reclaimed material with ammonia. The ammonia remaining in the water is removed in a vacuum degassing plant to make the water suitable for re-use. Entwistle *et al.* (68) describe a method for the recovery of zinc sulfate from spent viscose rayon spinning waters. The zinc is precipitated from the neutralized liquor as the hydroxide, the precipitate is dissolved in sulfuric acid, and the zinc sulfate is recovered. Bergstrom and Trobeck (23) describe a method for evaporating to dryness waste waters from the manufacture of cellulose by the sulfate process. Antykov (20) says that the finely dispersed sulfur deposited in the spinning process in the manufacture of viscose fiber can be continuously removed by extraction with carbon tetrachloride. Roznoy (187) reports on an investigation of aerobic and anaerobic treatment methods in the treatment of wastes from a Celanese Corp. plant in Charlotte, N. C.

Nemerow (161) says that cotton kier liquors can be partially purified by coagulation and that dilute liquor can be treated by biological filtration. Masselli and Burford (129) made a study of the wastes from cotton finishing and found that 70 to 80 per cent of the B.O.D. in the plant effluent was from the chemicals used and only 20 to 30 per cent of the B.O.D. actually came from the natural waxes and pectins extracted from the cotton. Nemerow (162) in writing about the enzyme desize and starch rinse waters from the manufacture of textiles, says

that more than 99 per cent of the volume of the wastes arises from the washing of the converted starch from the goods. The wastes can be treated by adapted dispersed seed and oxidation, with removals of 95 per cent in seven days. Kehren (102) says that mixed textile wastes can be treated with a 10 per cent solution of ferric chloride when the waste is adjusted to pH 6.0 to 6.5. Experiences with the operation of trickling filters being fed textile wastes from bleacheries and dyehouses have been reported by Dahlem (49). The best results were obtained when one part waste to three parts of recirculated water was distributed on the filter.

Wool Scouring

Collins (43) discusses the use of the C.O.D. test in determining the strength of wool scouring wastes. McCarthy (133) says that 0.25 to 1 lb. of B.O.D. can be expected from the processing of 100 lb. of dyed wool and that treatment of the undiluted waste mixed with domestic sewage can be accomplished on percolating filters. Taylor (228) says that wool scouring wastes can be treated by adding calcium chloride to the waste less than 3 min. before centrifuging. This method separates the sludge which forms when the emulsion is cracked. The New England Interstate Water Pollution Control Commission (128) published a 31-page report on the character of and methods for treating wool scouring wastes.

Tannery Wastes

Taylor (227) tells about tannery wastes discharge to a stream at Ayer, Mass., that caused deterioration of the town's well-water supply. The waste waters are now mixed with domestic sewage and treated by biological filtration at the municipal sewage works. Dular (60) reported on a method for treating tannery wastes containing albuminoid materials by coagulation with the correct proportion of tannins and pH control after neutralization. Southgate (212) is of the opinion that there currently is no satisfactory method for treating tanning wastes and believes that it is first necessary to have a concerted drive to reduce the sources of waste in the tanneries before it will be feasible to treat the waste waters.

Mathis (131) conducted laboratory and plant-scale experiments on the treatment of tannery wastes. Physical methods included screening, settling, and centrifuging. Of these, only screening through 1-mm. screens proved practical, giving 50 per cent removal of settleable solids and 12 per cent removal of B.O.D. Chlorination with 7,080 p.p.m. of chlorine reduced the B.O.D. by 53 per cent after 24-hr. contact. Flocculation with 5,000 to 9,000 p.p.m. of ferrous sulfate reduced the suspended solids by 97 to 99 per cent and the B.O.D. by 19 to 56 per cent.

Pulp and Paper Wastes

The work of the National Council For Stream Improvement (151) is summarized for 1953 in a publication covering sulfate, sulfite, semi-chemical, strawboard, and white water effluents, stream analyses and aquatic biology.

Murdock (149) reviews the development of the wood pulp industry, its waste problem and the trend in ameliorating this problem.

One of the outstanding recent developments in the treatment of sulfate (kraft) mill effluents has been the biological oxidation of selected effluents using a modification of the activated sludge process. Bishop (25) describes a plant installation for the treatment of decker seal pit effluent by means of this process. B.O.D. reductions in the range of 60 to 85 per cent are attained with initial B.O.D. values ranging from 200 to 500 p.p.m. The plant operates with a minimum of attention and maintenance. The treated and clarified effluent is added to a much

larger volume of untreated effluent in oxidation lagoons, resulting in a large increase in the rate of stabilization of the mixture. The net result is a decrease in required detention time, permitting the handling of much greater volumes of untreated effluent in the same oxidation lagoon capacity. Bishop and Wilson (26) describe the complete treatment of the effluents at the above installation. They describe the laboratory and pilot plant work which lead to the development of the present system used, which includes treatment of a portion of the effluent by the modified activated sludge process, oxidation lagoons for the total mixed effluents and natural purification in an 8-mi. ditch. The B.O.D. load of 18 tons per day is reduced to 1.5 tons in this manner. Miller and Kniskern (144), describe a 700-ton-per-day sulfate and semi-chemical plant making unbleached and bleached paper and paperboard. In-plant control practices are summarized. Pilot-plant studies of the modified activated sludge treatment of selected effluents with B.O.D. reductions of 80 to 90 per cent are described. Nitrogen and phosphorus salts are added to make up deficiencies. The unusual qualities of the sludge stability include its resistance to putrescent decomposition and ability to withstand shock loads of high pH and high B.O.D. Moggio (146) discusses the pollutional characteristics and volumes of sulfate effluents. In-plant changes and improvements in process equipment and operations which have resulted in appreciable improvements in effluent quality are covered. Methods for effluent handling, treatment, and disposal are summarized.

A statistical analysis (155) was made of B.O.D. and permanganate O.C. values of the kraft pulp and paper mill wastes to determine to what degree the O.C. test could be substituted for the B.O.D. test. The results showed that O.C. could be used for control purposes with total waste and only as a very rough indicator of the effluent B.O.D. The following relationships were obtained:

B.O.D., total waste (p.p.m.) = 0.643 × O.C. (p.p.m.) and

B.O.D. ave. effl. (p.p.m.) = 0.094 × O.C. (p.p.m.) + 0.43

Siekierzynska and Zielinski (207) describe the treatment of sulfate effluents by coagulation with lime, sulfuric acid, and ferrous sulfate-calcium hypochlorite. Oxygen-consuming properties were reduced 50, 50 to 80, and less than 50 per cent, respectively. In a French patent issued to Vernudachi (239) the treatment of alkaline effluents with chlorine resulted in the conversion of the free alkali to hypochlorites and alkaline chlorides and the oxidation of organic matter. The re-use of bleach plant waters and white waters in sulfate pulp bleaching operations, with specific applications, is described by Doutt and Fluharty (158). Information concerning water balances and losses of oxygen-consuming materials from various unit processes in sulfate mills is offered by McDermott (157). Suggestions for the re-use of condensates are offered as a means of reducing the pollution load of plant effluents. Hassler and McMinn (83) describe a process for active carbon production from sulfate black liquor.

In the field of soda pulping, Drummond (58) details how the modernization and installation of new equipment in a soda mill resulted in great improvements in effluent quality. Oldaker (164) describes experiments with chemical and biological treatment of spent liquors used to prepare flax for specialty papers. He concludes that chemical treatment is impractical, resulting in large amounts of sludge and maximum B.O.D. reductions of only 50 per cent. Dilution of the spent liquors followed by trickling filters resulted in 57 to 72 per cent B.O.D. reductions.

The literature on spent sulfite liquor from sulfite pulping is replete with methods, patented and unpatented, for

the preparation and utilization of by-products. Marshall and Neate (126) prepared a bibliography of the 1953 literature dealing with the subject. Fermentation processes appear to have the most appeal as by-product production methods. Naldi (150) describes a process for the production of volatile fatty acids; Kin (106) reports on the production of vanillin and lignin by fermentation, hydrolysis in alkaline medium, and oxidation with air in presence of $CuSO_4$. Vanillin is extracted with toluene or xylene and lignin and Na_2SO_4 are isolated. The economics of butyric acid *versus* ethyl alcohol fermentation are discussed by Schoedler (195), who states that better yields of butanol and acetone are obtained by the former method than by synthesis from ethanol, and at lower costs. Taketomi, Shizawa and Ueda (224) produce calcium lactate and lactic acid from spent sulfite liquor by removing SO_2, liming to pH 9, filtration, and neutralization with CO_2 followed by fermentation. Taketomi, Shizawa and Tanaka (223) describe the preparation of food and fodder yeasts utilizing the same general procedure. The economics of fodder yeast production with particular reference to the Pacific Northwest is reported by Schleef (194). Laboratory studies show the possibility of one ton of dry yeast from the spent sulfite liquor obtained from the production of 10 tons of pulp. Samuelson (192) describes the use of flue gases from the combustion of evaporated sulfite liquors to neutralize additional spent liquor before fermentation for alcohol production. A distillation process is described (7) for the production of ethyl alcohol by fermentation. Production by this process in a Canadian plant results in 2.5 to 3 m.g. of 97 per cent ethyl alcohol annually. The preparation of tanning materials from spent sulfite liquor is described by Zak (255) and Anderson (6). The latter describes a method utilizing acid organic cation exchange material. Salvesen *et al.* (190) describe a patented process for preparing vanillin from lignosulfonates by heating with NaOH in the presence of air or oxygen. The production of synthetic resins through the condensation of acid sulfite lignin with phenol and formaldehyde is described by Scipioni (200). A method for the recovery of organic matter from spent sulfite liquor through treatment with CaO is described by Kleinert (107). The recovered material may be used in plastics or as fuel, fertilizer, and soil conditioner. The recovery of sulfur is also possible. Uschmann (235) and Huttenes (94) describe patented processes for the preparation of binding agents from spent sulfite liquor while Salvesen, Browning and Harmon (191) and others (89) described patented methods for the preparation of dispersing and wetting agents. The preparation and productions of ion-exchange materials are described by Kin (105) and Andersen (5).

The preceding references relative to the utilization and preparation of by-products from spent sulfite liquors reveal the preponderance of foreign patents and publications. This emphasis on by-products recovery undoubtedly results from the less favorable economic conditions and lack of cheaper raw materials in these countries as contrasted to the conditions existing in the U. S.

In the field of spent sulfite liquor treatment, Zimmerman (258), in a patented process, heats the liquor under high pressure while air and lime are injected concurrently. At a pressure of 1,500 p.s.i. and 518° F. the liquor is flashed off, releasing N_2, CO_2, and excess air. The treated liquor exhibits an oxygen demand reduction (iodate) of more than 98 per cent. No catalysts are required nor is there any evaporation or combustion involved. The reaction products are innocuous gases or solids. Ganczarczyk and Domanski

(73) report on chemical treatment of spent liquors using alum, ferrous sulfate, chlorine, milk of lime, and CO_2. Chemical dosages required are uneconomically high. Lime treatment appears most satisfactory because of recovery and re-use possibilities of the lime. Haywood (84) describes laboratory and patented methods for the recovery of soda and sulfur from acid sulfite liquors. Soderlund, Lindberg and Simmons (210) and Simmons (208) describe a burner for the incineration of evaporated spent sulfite liquor. Hull *et al.* (93) and Markham and McCarthy (124) discuss ammonia base sulfite pulping, with the latter describing a process for recovery of 60 to 65 per cent of the ammonia using an ion exchange resin.

A study (156) was undertaken to determine the effect on the receiving stream of converting from calcium to soluble ammonia base sulfite pulping. In streams deficient in nitrogen, such a conversion would result in increase in the rate of biochemical oxidation of the organic load and thus in a greater deoxygenation of the receiving stream.

The methods for white water clarification, with characteristics of the various types of equipment used, are reviewed by Gehm and Lardieri (76). Along the same line, Van Horn (238) discusses the use of save-alls, sedimentation with and without chemical coagulation, and filtration. Ganczarczyk and Domanski (74) report laboratory studies of chemical treatment of white waters. The sludges produced could not be re-used because of the lack of long fibers and the presence of considerable ash. Eden, Jones and Wheatland (63) treated white waters by trickling filter preceded by pH adjustment, chlorine removal, and the addition of N and P compounds, all of which resulted in a costly process. The disposal of white water from hardboard manufacture by irrigation on cultivated land is reported by Burgess, Frost and Merryfield (35). The possible use of activated silica sols in the treatment of paper and board mill white waters is suggested and outlined by Klinger (109). In a critical survey of the literature on the dehydration of hydrogels by Beck (159), the conclusion is reached that the use of air flotation to concentrate the fibers and spray drying to recover the fibers would be the only economic and satisfactory methods for the clarification of white waters.

Bloodgood (152) reports that anaerobic digestion of strawboard pulping sludge will produce a material which can be disposed satisfactorily. Due to the large amount of sludge produced, the economics of applying anaerobic digestion require the development of higher digestion rates than can be obtained presently.

Betts, Copenhaver and Reaves (24) describe a treatment plant using a modified activated sludge process for the treatment of a mixture of semi-chemical and chipboard pulping effluents and machine-water effluent. Ammonia is added to the return sludge. With an effluent of 250 p.p.m. B.O.D., 84 per cent reduction is obtained with loadings of 46 lb. of B.O.D. per 1,000 cu. ft. of aerator capacity. Opferkuch and Watkins (154) present a detailed description of laboratory studies, including material balances and cost estimates, concerned with the recovery of acetic acid from evaporated spent semi-chemical liquors. Distillation and solvent extraction methods were investigated, with the former exhibiting more promise based on economic considerations.

Stanley and Ellis (217) present the description of a treatment plant at a sewer pipe and conduit factory which uses waste paper as one of its major raw materials. The major waste flow originates from the pulping and washing of the waste paper. Nadelman, Newton and Palladino (153) describe experimental work directed toward the

utilization of deinking waste solids. Since the recovered products cannot be utilized completely back in the paper industry, uses in other industries were investigated. Among the possibilities investigated was the use of the solids as fillers and building materials.

Petroleum Processing

The literature reveals an increasing interest in biological processes for treating refinery waste waters. Hamdy, Sherrer, Weiser and Sheets (82) (202) have studied extractive, adsorptive, catalytic oxidative, and biological processes for treatment of effluents from catalytic crackers and conclude that only the last-named is economically suitable. A miniature trickling filter provided means for selecting phenol-utilizing microflora. The organisms, as yet incompletely identified, destroyed phenol concentrations of 400 p.p.m. at a rate of 0.9 to 1.2 lb. per sq. yd. of stone per day. Lactose was detrimental, while several inorganic salts stimulated phenol destruction. Vigoro, a commercial fertilizer, in 0.1 per cent concentration, was a good stimulator. Strong and Hatfield (220) report successful use of the activated sludge process to treat a toxic petrochemical waste of high oxygen demand. The waste is discharged at 400 to 700 g.p.m. with a 5-day B.O.D. of 11,000, chemical O.D. of 30,000, and formaldehyde 6,000 p.p.m., at pH 4.5. By increasing the returned sludge rate, maintaining an unusually heavy concentration of suspended solids, and recirculating treated effluent at a high rate, B.O.D. removal was 80 and 99 per cent for loads of 365 and 183 lb. B.O.D. per day per 1,000 cu. ft. of aeration volume, respectively.

An important feature of the Sarnia refinery is the use of biological oxidation to destroy phenol in waste process water. Cushnie (48) states that this waste first flows through an A.P.I. separator and then is aerated in a tank seeded with *Achromobacter cruciviae*, which oxidize the phenol to CO_2 and water. The bacterial floc is settled and pumped back to the aeration tank. In winter it is necessary to heat the water to maintain bacterial activity. During plant shutdowns the bacteria are fed with purchased phenol. Austin, Meehan, and Stockham (21) found that a pilot trickling filter fed at 8.5 to 42 m.g.d. per acre successfully removed oil and phenol from refinery waste water. Removal of pollutants per unit of bed volume increased with increasing feed rates, but percentage removal decreased. Recycling effluent improved removal of oil and phenol, but not odor or B.O.D. Mau (132) reported a 3-month pilot study of wastewater treatment in which alum and activated silica were used to condition the waste for treatment on a trickling filter. Phenol removal ranged from 99.6 to 93.3 per cent for loadings of 25 to 300 p.p.m., respectively. An occasional slug of raw waste with pH 11 did not have an adverse effect on the filters. Storage of filter effluent in an oxidation pond for 60 days prior to discharge is recommended to absorb shock loads.

Crosby, Rudolfs, and Heukelekian (47) made laboratory and field investigations of biological growths in refinery wastes, including studies of their occurrence, nature, causes, and control. Growths were found in all parts of refinery waste-water systems, but they were not of equal significance at all refineries. There were two types of abundant growths: filamentous blue-green algae (*Oscillatoria*) and bacterial zoogloea or slimes (primarily Gram-negative short rods); only the latter were considered objectionable. Primary seeding was apparently from soil and marine sources. Barometric condenser water stimulated slime growths. Reduced sulfur compounds and petroleum hydrocarbons were also stimulatory where D.O. was low. The slimes adsorbed oil, which was released as a

visible film following deterioration in the receiving water. Slimes were effectively controlled by intermittent daily injection of chlorine or sodium hypochlorite sufficient to produce a 15-min. residual. The high adsorptivity of these slimes suggests a potential biological finishing treatment for refinery effluents.

According to Phillips (172) the major pollutional materials in petroleum refinery wastes are naphthenic and sulfonic acids. These form oil salts or soap emulsions that clog the separators. Water from crude oil desalters contains high concentrations of calcium and magnesium salts which under alkaline conditions precipitate in sewers and act as finely divided solid emulsion stabilizers. Treatment of refinery wastes at Baytown, Tex., consist of acidification and settling of the chemical wastes in an impounding basin to remove organic material, and neutralization with lime, followed by clarification and filtration of the settled sludge.

Chrysler (17) treats waste water containing cutting and soluble oils, solvents, and crankcase oils by coagulation with silicate, followed by alum and sodium aluminate. The floc is removed with a Colloidair separator. Rohlich (186) studied air flotation as a means for treating refinery waste water. On water from an A.P.I. separator he found that maximum oil removal occurred with an air rate of 10 cu. ft. per hr. Addition of 4 to 12 p.p.m. alum and 4 p.p.m. activated silica increased oil removal 15 to 23 per cent over air alone. At one refinery (18) all phenol-containing waste waters are segregated and steam-stripped of sulfur compounds in a tower packed with Raschig rings. The stripped water is used as cooling-water make-up. Aeration in the cooling tower apparently encourages bacterial growths which destroy the phenol. Waste caustic solutions are blown with flue gas and the phenolic layer, which separates and is removed. Effluent from this operation is also returned to the cooling-water system. Eaton, Evans and Kominek (62) discuss reuse of treated refinery effluents, especially for make-up to cooling-water systems. They point out numerous difficulties that might be encountered where such re-use is practiced.

The electric-mercaptan, the electric-H_2S, and the amine-salt-H_2S processes are said by Zandona and Rippie (256) to provide oil refiners with new tools to obtain low-cost desulfurization and combat stream pollution. Weston and Merman (248) describe in detail the chemical treatment process used by Atlantic. Stormont (218) reports that General Petroleum uses an underground skimming pit under vacuum for oil recovery. McRae (139) states that cracker effluents plus caustic washing water are treated countercurrently with flue gas, air, and steam at 200° to 250° at 6 p.s.i. in a stripping column. The gases are burned, and the bottoms, after separation of phenol, are treated with soil bacteria fed with phosphate and nitrate. Elkin and Soden (67) compare the operation of old and new waste-water treatment systems at Marcus Hook, Pa. The new system, which handles segregated process water, is much more efficient than the old one, which serves a combined sewer system. Dennis (53) provides helpful details for planning a survey of refinery waste streams. Cashmore (40) states that the A.P.I. Committee on Disposal of Refinery Wastes is the recognized authority in Canada. He lists the contents of the manual published by that Committee, which details the methods used for treating refinery effluents. Calise (37) describes the performed-floc oil-removal filter. It reduces oil to below 0.2 p.p.m. by using a hydrated alumina floc fed at a ratio of 0.2 to 0.5 p.p.m. per p.p.m. of oil to be removed. It works best with oil concentrations of less than 25 p.p.m. Details of the operation are given. The same author (38) reports

on removal of color from refinery effluents by adsorption on freshly-formed hydrated ferric oxide.

Recovery of iodine from oil-well brines is described by Allen (2). Oil and other impurities are removed by flocculation with $FeCl_3$. The brine is treated with chlorine and blown with natural gas in a countercurrent scrubbing tower at 3,000 to 4,000 p.s.i. and 95° to 100°. The gas is expanded to 500 to 1,200 p.s.i., and the iodine crystallizes on ceramic packing. The gas stream is recompressed and recycled. Dickey and Weaverling (54) claim to recover cresylic acids from caustic washing solutions by scrubbing with oxygen-containing hot flue gas generated by submerged combustion. Bellet (22) states that light phenols and pyridines can be recovered from oils by treating them with phenolated water acidified to pH 2 to 3. The aqueous extract is treated with butyl acetate; phenol is recovered from the acetate by distillation. Pyridines are recovered from the aqueous solution by a succession of distillations. The treated oil containing heavy phenols is treated with caustic soda and steam distilled to yield 98 to 99 per cent oil completely free of phenols and pyridines. This treatment prevents discharge of phenolic process water.

A process for treating spent caustic solutions is claimed by Schull, Robertson, and Knowlton (197). Treatment with a ferrous salt at pH 12 removes phenols. Addition of acid to pH 8 to 11, plus more ferrous salt, removes sulfur compounds. Knowlton (112) describes a somewhat similar process in which the spent caustic is combined with steel pickling liquor in a ratio to provide a pH of 6 to 11.5. After separation of the precipitate the solution is acidified to pH 4 to separate additional phenol as an oily layer. Hendel and Day (86) treat spent caustic with flue gas to pH 11 to remove sulfur compounds. Addition of H_2SO_4 to pH 9 then causes separation of a phenolic layer, which can be skimmed off. This two-stage neutralization is said to overcome difficulties encountered in similar processes. Resen (184) describes a plant for making 98 per cent H_2SO_4 from acid sludge. At another plant (9) 400 tons of 98 per cent H_2SO_4 per day is made successfully from sludges containing as little as 65 per cent acid; previously, sludges with less than 82 per cent acid could not be handled.

Oil fields in the coastal counties of southern California produce about 25 m.g.d. of waste water, most of which is discharged to the ocean. Pomeroy (176) states that the Los Angeles County Sanitation District has liberalized requirements for acceptance of such water in its sewer system to 10 p.p.m. flotable and 600 p.p.m. total oil. Pilpel (175) reports that an international conference agreed to fix zones in which discharge of oil at sea will be prohibited. For vessels over 500 tons, no discharge will be allowed closer than 50 mi. from any coast (100 mi. in the North Sea). The Institute of Oceanography is studying the speed and direction of ocean currents which carry oil to coastlines. Coogan and Paille (44) concluded that deoxygenation of receiving waters by immediate O.D. is the most important pollutional effect of refinery effluents. McRae (140) described a long-range investigation of the Ontario Research Council on phenol pollution from refineries and chemical plants. Similar projects are slated for Alberta and Quebec. Ruchhoft, Middleton, Braus, and Rosen (188) found that neutral aliphatic and aromatic hydrocarbons are the principal source of tastes and orders in refinery waste waters. Turnbull, DeMann, and Weston (233), on the basis of extensive laboratory study, report that relatively simple chemical control tests can be used after permissible concentrations of toxic wastes have been established by bioassay procedures. Hueper and Ruchhoft (92) found that four eluates of carbon adsorbates of

raw water polluted by refinery effluents were weakly carcinogenic when painted on the skin of mice. Eluates from raw water polluted by various other industrial wastes gave negative results. Since these results were obtained with active agents in highly concentrated form, the public health aspects of the finding are uncertain.

Steel Production

An excellent guide to the blast furnace department of the steel industry (27) outlines the manufacturing process, volumes and character of the wastes produced, and remedial measures to prevent pollutional effects. The suspended solids from blast furnace gas wash water can be recovered, sintered, and re-used as a portion of blast furnace charge. Phenol, cyanide, and fluoride, although relatively low in concentration, may create objectionable pollution.

Howell (91) described the treatment facilities for steel production wastes at the Fairless Works. The wastes consist of oils, acid and alkaline wastes, mill scale, flue dust, etc. Segregation of wastes according to their essential characteristics and combination to bring about effective treatment was used in the design. Acid pickling liquor solution is disposed of by trucking to a manufacturer for utilization. In case of breakdown in truck disposal, neutralization equipment has been provided. Alkaline wastes are utilized for neutralization of acid wastes. The terminal treating plant handles the entire flow of waste with the exception of blast furnace dust waste.

The general problems in the design, construction, and putting into operation of the waste treatment facilities of the Fairless Works was presented by Nebolsine (160). The treatment of flue dust waste at this plant was presented by Henderson and Baffa (87), of sheet and tin mill wastes by MacDougal (122).

Reclamation of the wastes produced by Kaiser Steel Co. plant at Fontana for re-use as make-up water was discussed by Joseph (98).

Pickling and Acid Wastes

A low-cost process for neutralizing pickle liquor has been installed at a number of steel fabricating plants. Dahlstrom (50) states that operating costs are $0.018 to $0.02 per gal., depending on acid strength. The process yields a readily filterable slurry; the filter cake is about 50 per cent dry solids. A flowsheet and operating data are given. Parsons and Heukelekian (167) have studied scale deposition following lime neutralization of H_2SO_4 waste water. They found that extensive supersaturation with $CaSO_4$ is confined to a limited range of acid concentration equivalent to the solubility of $CaSO_4 \cdot \frac{1}{2} H_2O$. An 80 per cent reduction in scaling resulted from addition of 5,000 to 15,000 p.p.m. of gypsum seed crystals. Martin (127) patented a process for continuous regeneration of spent pickling solutions wherein concentration of the liquor causes the $FeSO_4$ to crystallize as the monohydrate, permitting return of the mother liquor to the picklers. Ruthner (189) developed a pickle liquor recovery process in which $FeSO_4$ is converted to $FeCl_2$ by mass action of an excess of HCl gas. The chloride is filtered off, calcined, and the HCl recycled. The mother liquor is stripped of HCl and the H_2SO_4 returned to the picklers. It is reported that a group of American steel companies plan to pilot this process. Shaw (201) patented a pickle liquor recovery process in which the liquor is concentrated by evaporation to saturation with $FeSO_4$. Addition of H_2SO_4 then precipitates the $FeSO_4$ as monohydrate.

Plating and Cyanide Wastes

Pettet and Mills (171) investigated the effect of simple and complex cyanides on sewage purification in a labora-

tory-scale trickling filter. With a filter acclimatized to CN, more than 99 per cent was destroyed in sewage or water containing 100 p.p.m. HCN as KCN or complexes of Zn or Cd, and 75 per cent where Cu or Ni complexes were present. Renn (183) studied the potential effect on ground water of lagooning CN wastes. He found that CN will break through sandy-clay soils in two weeks with 100 p.p.m. CN solutions at a one-day flow-through time.

The electroplating waste treatment plant installed by Oneida, which has received a great deal of publicity, is comprehensively described by Walker *et al.* (243). This plant handles 20,000 g.p.h. of complex plating waste and discharges a completely innocuous effluent with recovery of 99 per cent of the silver formerly wasted. Simpson and Samsel (209) describe a small batch plant for removal of CN with hypochlorite, and Cr^6 with metabisulfite. Costs of construction and operation are given. Dural (61) patented a process for disposing of CN wastes by spraying them into a solution of $FeSO_4$ whereby non-toxic ferri- and ferrocyanides are formed. [Reviewer's caution: Sunlight liberates HCN from ferrocyanides.] Poole, Holtje, and Belter (177) discuss cyanide spills in Indiana. They point out that the principal cause of cyanide spills is tank overflow, not tank failure.

Recovery of Cu and Ni from rinse water discharged from Cr electroplating bath by ion exchange permits its use as bath make-up (56). Brink (33) describes recovery of Cr from anodizing rinse water by conversion to Na_2CrO_4 with NaOH and passage through duplex anion- and cation-exchange units. The cation unit also removes Al. Kemper (104) is said to have found a process for precipitating Ni in filterable form from dilute solutions. Removal is reported to be practically complete, but the process is not yet fully developed. Shimatani and Toshimasa (204) have patented a process for recovery of Ni by passing the solution over pieces of electrolytic Ni tempered at 500° for an hour. Gaylor (75) patented a process for electrolytic regeneration of spent caustic containing oxidizable sulfuritic impurities. Ingols (95) discussed the mechanism of Cr toxicity.

Lieber and Welsch (118) report heavy contamination of ground water by Cd where recharge basins were used for waste disposal. This has created a hazardous situation because the local population depends almost entirely on wells for drinking water. It will be many years before ground-water dilution will restore this water to potable quality. Watson (245) has written a full description of plating waste disposal at the Erie plant of General Electric. Wise (252) in discussing this paper gave experiences in Connecticut with plating waste treatment plants. Paulson (168) reports that water shortage prompted installation of a cation exchanger for recovery of plating rinse water for re-use. Lancy (116) described an integrated process for re-use and recovery of plating wastes. Swartz (221) stated that at a small plating establishment, proper segregation and combination of wastes permitted discharge to city sewers. This change in plant drainage reduced the concentration of contaminants below those established for drinking-water quality. A variety of good housekeeping methods, described by Parks (166), was effective in reducing pollution from a Cr-plating plant.

Coal Wastes

A comprehensive report covering six years of research on coal mine drainage has been released by Braley (30). This is a highly useful factual account of mine acid formation and the various practical and impractical control measures that have been used. Powell (179) discusses the effects on ground water of drainage from coal and ash storage piles. Temple and Koehler

(229) describe mine acid formation and attribute part of the oxidation of sulfuritic material to bacterial activity.

Measures that can be used to eliminate or reduce pollution from coal preparation plants are discussed by Gilbert (79). A specific installation using cyclone thickeners and closed water circuits is described by Charmbury (41). Froth flotation of coal fines has some debatable features, which are discussed by Lowes (121). Economics and operational details are dealt with. Siebert (206) discusses methods for recovery of silt at coal preparation plants and states that a flat standard of 1,000 p.p.m. of suspended solids in effluents from both bituminous coal and anthracite collieries is one that could be met by coal operators. The author remarks that this standard has been very convenient for enforcement purposes. Pennsylvania has long favored effluent standards because they are easy to enforce; this is a rather doubtful reason for deciding upon criteria for stream pollution control.

One coal company successfully uses a closed-circuit system for handling rejects. Flume water is recirculated to a fresh-water reservoir; this practice has been quite advantageous during droughts. Weimer (247) gives full details of the operation, including economics. Restoration of the Schuykill River by dredging coal silt and requiring treatment of waste water at collieries has been a noteworthy achievement (19). Levin and Ledvina (117) give full details of the recovery of coal silt from the Susquehanna River for power generation.

By-Product Coke Wastes

Pilot-plant studies of a German process for treating coke plant waste water were reported by Schulz (198). The pH of the waste is adjusted to 6.8 with CO_2. It is filtered through gravel to remove oil and suspended matter, then sent to an ion-exchange unit containing Wofatit P for removal of phenol, which is recovered by extraction of the bed with methyl alcohol. Phenol was reduced to 5.5 from 7,600 p.p.m. and the 5-day B.O.D. was reduced about 96 per cent. Zavadlal (257) reported what appears to be a most unsuccessful phenol recovery process. A volume of 100 cu.m. of gas liquor was continuously treated with phenolsolvan (butyl acetate) equal to 10 per cent of the volume of liquor. The daily loss of phenolsolvan was 35 kg. and the maximum reduction of phenol was 0.2 g. per l. Wiegman (249) traced the history of phenol recovery in the Emscher region since 1929. Extraction with benzene is common practice and 500 tons of pure phenol is produced annually. McCord (135) described a modern phenol recovery unit using benzene extraction at Lackawanna, N. Y. Efficiency of phenol removal is 98.8 per cent. A countercurrent centrifuge-extraction process employing benzene is reported by Kaiser (100) to reduce phenol in ammoniacal gas liquor to 5 from 2,000 p.p.m. The process is said to be economically competitive with column extractors. Duchemin and Lecomte (59) described adsorption of phenol on activated carbon, from which it was stripped with benzene. The carbon could not be regenerated with solvents or superheated steam.

Biological destruction of coke-plant phenols has received considerable research attention. Kliunkov, Pozolckaia, and Schneerson (110–111) indicate on the basis of pilot-plant results that the use of activated sludge rather than a pure culture is the best technique available for reducing the phenol content of wastes, but that the biological technique is not economical. Shibata (203) describes the steps required to reduce the phenol and ammonia content of a waste to the point of nontoxicity. Chlorine is used to destroy the phenol along with oxidation and lagooning. Meissner (141) reported

the results of a fundamental study of the mechanism of bacterial decomposition, which can occur both aerobically and anaerobically, but primarily through the action of liquefying, fluorescent bacteria. He found that bacteria will destroy up to 8.2 g. phenol per liter. Bringmann (31) and Do-Zent and Bringmann (57) found that *Nocardia rubra*, acclimatized by additions of 100-p.p.m. mineralized phenol solutions, destroyed 500-p.p.m. phenol in 24 hr. (1,600 p.p.m. in 48 hr.) if aerated with 1 l. air per liter of solution. Concentrations above 2,000 p.p.m. retarded growth. Cultures acclimatized to 1,000 p.p.m. phenol destroyed similar concentrations of *o*-, *m*-, and *p*-cresols. Taubert and Alleton (226) described an experimental bacterial plant in which phenol in ammoniacal gas liquor was reduced to 2 p.p.m. Pettet (170) states that water to be treated in a biological filter should not contain more than 0.25 per cent by volume of raw ammoniacal liquor. Thiocyanates and higher tar acids interfere with biological purification. Sorensen (211) described an interesting Swedish investigation. Effluent from a primary sewage treatment plant flows through four oxidation ponds in series. Biochemical oxidation by algae, protozoa, and bacteria occurs in the first three, while *Daphnia magna* consume algae passing to the fourth. Strongly acidic waste waters containing phenol were added in a range of concentrations to cultures of algae and *Daphnia*. At a concentration of 500 to 1,000 p.p.m. of waste, algae thrived but all *Daphnia* were killed in 10 to 12 days. Above 1,500 p.p.m. of waste, algae decreased in number. It was thought that, despite the toxicity of the waste, gradual addition would encourage development of organisms that would consume phenol.

Spent gas liquor from an English plant where the hot gas was electrostatically detarred could be added to sewage at 2.5 per cent by volume without affecting operation of the sewage plant (11). Marsden (125) reported that ammoniacal gas liquor is a valuable source of nitrogen fertilizer in many cases. Another report (13) states that such liquor has been outstandingly successful on Scottish grassland. Cooper, Priestley and Marshall (45) patented a process for making fertilizer by treating ammoniacal liquor with HNO_3, filtering, and concentrating to crystallize ammonium salts. Burden and Robinson (34) patented a process whereby concentrated ammonia liquor is treated with 40 per cent of the amount of copperas required to neutralize the NH_3. The mixture is filtered, more ammonia liquor is added, and the liquor filtered again. Concentration of this filtrate yields Fe-free $(NH_4)_2SO_4$. In another process (12) crude ammonia liquor is contacted with an oxidizing gas at elevated temperature and superatmospheric pressure in a packed column. Free ammonia is recovered from the reaction gas. Evans (69) recovers sulfur from spent iron oxide by treating it with superheated steam in a fluidized bed, thereby removing 80 per cent of the sulfur. Tanemura *et al.* (225) described a process for recovering pyridine from coke-oven gas. Gas from the saturator was scrubbed with 15 per cent H_2SO_4. This liquor was combined with mother liquor from the saturator and the pH raised with ammonia to free the bases. The process recovers about 97 per cent of the tar bases in the gas. Data on a German plant for purification of coke-plant effluent suitable for discharge to municipal sewers were reported by Jungeblut and Osterloh (99).

The Collins process (14), which was developed in England for desulfurizing coke-oven gas, has attracted recent attention. The particular features of the process are: (a) use of dilute ammonia solution as the desulfurizing medium; (b) spraying the washing liquor through specially designed noz-

zles in unpacked towers in a number of stages; (c) achievement of preferential absorption of H_2S over CO_2; and (d) cyclic operation. Experience has shown that 70 to 80 per cent desulfurization can be attained, but strict control of the deacidification process is essential. Williams (250) described the first English installation of the Collins process combined with the Chemiebau wet-contact sulfuric acid process.

Edmonds and Jenkins (64) gave full details of a continuous countercurrent solvent extraction process for recovery of phenol from waste water produced at a coal hydrogenation plant. The process is said to be extremely efficient. Davankov and Ogneva (52) report success in removing phenol from waste water by ion exchange on a laboratory scale. The resins are regenerated with NaOH or NH_4OH. Lorenz (120) reported data on removal of phenol by mixing with an aqueous suspension of fly ash from power plants.

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WATER POLLUTION

Biology

Plant or other growths in domestic or industrial water supplies may create a variety of problems, many of which are intensified by pollution. Among these are tastes and odors, filter clogging, undesirable blooms, changes in water quality, and toxicity. Various methods and materials have been used for their control.

Tastes and Odors

Wells (255) emphasizes the importance of facilities to make possible treatment for tastes and odors due to microorganisms at any point in the water treatment process, since each case is a separate problem. Matheson (154) also refers to the variety of treatments needed to combat tastes and odors and the need for selecting a treatment according to the cause and severity of each particular outbreak. Harlock and Dowlin (108) had success in elimination of odor due to algae by maintaining sufficient residual chlorine in the water. Fox (99) lists the factors in the environment which produce optimum conditions for taste and odor algae while Turre (239) had published photographs of a number of

taste and odor organisms and mistakenly includes bacteria, fungi, and protozoa under the term algae. Palmer and Walter (184) report plans for publication of colored illustrations of taste and odor, filter clogging, film-forming, and other algae of importance in water supplies, together with keys for their identification. A new handbook by Prescott (192) will also aid in the identification of algae.

Silvey (213) has continued his series of articles on actinomycetes in relation to water supplies with suggestions for their isolation and culture. Perlman (185) summarizes the physiological studies on actinomycetes, which are able to oxidize carbohydrates and lipids to CO_2. Most of them attack proteins and polypeptides and also are able to utilize nitrates and ammonia.

Algal Control

Reports on the control of algae and other organisms in the raw-water supply indicate several variations in the use of copper sulfate. Derby *et al.* (78) (79) found that continuous addition of copper sulfate to maintain a concentration of 1.0 p.p.m. at the outlet of the reservoir was effective at Los Angeles, while Nesin and Derby (174) report control of *Synura* in New York with only 0.24 p.p.m. applied after the organism appeared. Czensny (70) observed that low concentrations of copper appeared to be more effective than large amounts, and that evidence of excess copper could be obtained by comparison of the copper content of plants inside and outside of the treated area. Eidsness (85) states that a mixture of copper sulfate and citric acid was more stable in solution than copper sulfate alone and was much more effective.

Methods other than the use of copper sulfate for the control of algae are being reported by an increasing number of workers. Lawrence (136) reports the control of the branched alga, *Pithophora*, by dehydroabietylamine acetate (RADA), while McGowin *et al.* (156) state that RADA was unsatisfactory but sodium arsenite was satisfactory for control of that algae.

De Bussy (75) and Darragh and Stayner (72) have attempted, without full success, to check the growth of algae in swimming pools and industrial cooling systems with quaternary ammonium compounds. Jung (125), however, considers this treatment as the most modern method for swimming pools and bases its effectiveness on the removal of CO_2 from the water. Rensonnet (196) and Matheson (152) describe the use of microstrainers for elimination of plankton, while Stevenson (218) suggests the opening of scours to permit reservoirs to be washed clean at times of flood and the periodic emptying and refilling of reservoirs in order to reduce the likelihood of high plankton growths. Leibee and Smith (140) emphasize mechanical methods for removal of algae and the application of chemicals to create alkaline conditions in which phosphorus is precipitated and becomes unavailable as a nutrient for algae. Fitzgerald and Skoog (95) have continued their studies of 2,3-dichloronaphthoquinone (2,3-CNQ) as a selective algicide against bloom-producing blue-green algae. Tests on a 27-acre lake have indicated that it was effective at 30 to 55 p.p.b. Repeated applications were necessary for continuous control.

Bartsch (24), Lund (150), Matheson (153), and Swartz (224) (225), have summarized the practical methods now available for control of algae.

Control of Higher Aquatic Plants

Control of higher aquatic plants in reservoirs was considered by Steel and Ewing (217). Tests included borax, CMU, and 2, 4-D. Weeds, such as water milfoil, were controlled for a period of at least two years. The 2,4-D ester proved to be one of the most effective and was the least expensive.

Eggler (84) controlled water hya-

cinth with applications of 8 lb. per acre of 2,4-D, but alligator weed was only slightly affected. Loiselle (148) reports continuation of experiments with chemical weed killers on a public water supply watershed. Results with CMU showed that within 6 to 7 weeks no plants survived in the treated area and that growth was retarded for about two years. de Ong (77) has made a systematic survey of chemicals for the control of insects, fungi, and weeds which is useful for those whose responsibility for water quality requires them to be conscious of the possible hazards resulting from the wholesale use of such compounds as DDT, 2,4-D, lindane, chlordane, and others.

Pollutional Effects

A number of workers emphasize the changes in kinds and numbers of algae and other aquatic organisms brought about by pollution. Ryther (201) describes how pollution from duck farms favored the growth of the algae, *Nannochloris* and *Stichococcus*, over that of the more typical estuarine phytoplankton. Schulze (206) added $NaNO_2$ to a pond polluted by ducks and geese and which harbored growths of *Euglena, Boggiota, Coleps, Euplotes,* and *Chromatium*. Following addition of the nitrate, D.O. returned; H_2S odor and the organisms listed, except *Chromatium,* disappeared; and the green algae, *Scenedesmus, Ankistrodesmus,* and *Actinastrum*, developed. Junell (124) measured the effects of factory wastes in several locations in a Swedish lake by determining the "chlorococcal-desmidal quotient." The presence of many species of chlorococcal (and blue-green) algae were considered to indicate high pollution, whereas species of desmids (and armored flagellates) would be indicative of low or no pollution.

Kuhn (131) considered the changes in the net plankton population of Lake Zurich during a 60-year period involving pollution by sewage and drainage from manured fields. Sudden mass developments of new plankton show that the lake is now unstable. The importance of utilizing all modern technical knowledge to reduce the addition of nutrient matter to the lake is emphasized. Sawyer (204) refers to the algal blooms and other nuisance conditions resulting from the fertilization of lakes by sewage and other wastes and considers the many physical, chemical, and biological factors which influence these. Blum (37) reports on similar conditions in a Michigan river.

Flaigg and Reid (97) report that higher concentrations of nitrogen compounds in a polluted stream appear to accelerate the growth of algae so that they are concentrated in a shorter length of stream; for this reason the high nitrogen concentrations may be more damaging than low concentrations. Beauchamp (25), in Africa, found unpolluted streams to be so low in sulfates that lakes into which they flow had only limited growths of phytoplankton. Gerloff and Skoog (103) found that the bloom-producing alga, *Microcystis*, is capable of storing nitrogen and phosphorus nutrients in excess of its immediate needs and the amounts of these nutrients in the water, therefore, may be a poor indication of the amount of growth of which the alga is capable.

Blum (38) states that the pollution-tolerant diatom, *Nitzschia palea,* varies in numbers in a stream according to the time of day, the greatest number being found during the late morning and the minimum at night. Heusden (114) summarizes the information on algae in water supplies in Holland. He also emphasizes the great need for research leading up to a standard method for quantitative determination of algae in water. Palmer and Maloney (183) describe a new microscope slide for counting nannoplankton organisms, often disregarded in plankton counts. The slide permits use of higher magnification than is possible

with the conventional Sedgwick-Rafter slide. Sverdrup (223) derives an equation which helps to predict the development of vernal blooms of phytoplankton in the sea, based on certain hydrographic conditions. Lauff (135) found no correlation between phytoplankton count and water chemistry, while Verduin (242) showed that in western Lake Erie, the highest crops of phytoplankton arose in waters of intermediate rather than of low or high turbidity.

Marine organisms are now receiving increased attention in relation to pollution. Cribb (67) reported heavy surf pollution of the South Queensland coast to be caused by the algae *Colpomenia, Microdicton,* and *Enteromorpha.* Beger (27) cites the migration of the water shrimp, *Corophium curvispinum,* from salt to fresh water and its distribution in German streams, lakes, and waterworks.

Toxic Algae

Reports from several sections of the country indicate that at certain times of the year dense algal growths have produced toxic materials which have killed domestic animals, birds, and fish. Ingram and Prescott (120) have summarized information on toxic algae and have illustrated forms thought to produce a toxic material. These are all blue-green algae and include *Microcystis, Aphanizomenon, Anabaena, Nodularia, Coelosphaerium,* and *Gloeotrichia.* Shelubsky (210) reports that prolific blooms of blue-green algae occur in summer in fish ponds in Israel and heavy mortalities of fish result partly from oxygen depletion and partly from toxic substances. Shilo and Shilo (211) attribute fish mortality to the phytoflagellate, *Prymnesium parvum,* and suggest ammonium sulfate for its control. Alter (7) reports shellfish poisoning in Alaska is due to the flagellate, *Gonyaulax catenella,* which is used as their food. Grant and Hughes (105) suggest that the toxicity from algae might be associated with one particular stage in its development or decomposition. It appears that toxicity develops only gradually in blooms of the blue-green algae and decreases again as the algae decompose.

McLeod and Bondar (158) report animals died very shortly after drinking water from Lake Dauphin, Manitoba, which contained algal blooms of *Aphanizomenon flos-aquae, Anabaena flos-aquae,* and *Microcystis aeruginosa.*

Effects on Aquatic Life

Simmonds (214) reports that wood fiber discharged into the Spanish River formed a sludge on the river bottom which was densely populated by worms, but forms suitable as fish foods were scarce. Ferguson (92) found some fish kills in the Spanish River as far as 32 mi. below the source of pollution. Worms were the dominant bottom form over a distance of 20 mi. and fish from the stream had an objectionable flavor. Adams (1) describes an extensive fish kill on the Kalamazoo River, Michigan, where D.O. was absent for 40 mi. downstream, B.O.D. ranged up to 50 p.p.m., and H_2S reached 2.5 p.p.m. Costin (66) reported a large kill of eels and sea mullet in Upper Lane Cove River, Sydney, Australia, in a brackish-water area which receives industrial wastes rich in sulfur. Changes in the unsatisfactory environmental conditions in the lower Lippe during the period 1947 to 1950 are described by Bordo (40). The annual reports of the Severn River Board for the years 1951 to 1953 (208) indicate a marked deterioration in the quality of water in the upper Severn and severe pollution in the lower river, but some improvement was reported in the lower Tern and Frome. A reduction in the fishery values of the Rhine River due principally to industrial development and growth of towns is reported by Trahms (231).

A study of Alamitos Bay, California (195), showed conditions deleterious to aquatic life at one station where a

sulfide odor was detected; oysters had been killed. A study of bottom conditions in Los Angeles and Long Beach harbors, which receive sewage and industrial wastes (149), showed bottom fauna to be absent in some parts of the harbors. An ecological survey of the Castro Creek area in San Pablo Bay (93), which receives pollution from sewage and oil refinery wastes, showed a pH of 4.6, toxic chemical wastes, and no D.O. The bottom of the creek and estuary was devoid of animal life.

Results of a biological survey on the upper Moldau, Germany, which contains waste waters from paper factories, are reported by Nowak (177). The river is converted from an oligosaprobic stream, first to mesosaprobic and then to polysaprobic conditions below the discharge of the waste waters. A biological investigation in the estuary of the Avon and Heathcote Rivers, New Zealand, was made by Bruce (47). The rivers and estuary receive effluent from a sewage farm where sewage is settled and applied to land or treated in oxidation ponds. They also receive some trade waste waters, including the effluent from a starch factory. Progressive changes in the population of bottom organisms, as distances from the pollution sources increase, are given.

Protozoan populations from two areas of Pymatuning Lake, Pennsylvania, are compared by Orr (180). The population of an area subjected to swamp drainage was similar to that of an area receiving sewage, but more species were found in the sewage polluted area. Liebmann (142) reports on the first of a series of studies in Munich, under the title "Animal Parasites and Fish-Pathogenic Bacteria in Sewage and Fishing Waters." Lafon (134) found the fauna of the Rhone River at Lyons, France, to be characteristic of a rapid flowing, well-oxygenated water, low in organic matter. An improvement in the method of disposal of pulp mill wastes in Washington, and the results of a pollution survey, are described by Orlob and Eldridge (179). Fish kills which were observed in 1949 were not observed in 1951. Eldridge (86) cites the annual value of the water resources of the State of Washington as $292,000,000 and appeals for their protection for the economic welfare of all the people.

The pollution control agencies of the Pacific Northwest states are fighting to preserve the important salmon resources in the face of an expanding economy (87). A major problem is presented by toxic paper mill wastes. In Washington State (251) the following industrial wastes have been shown to be toxic to fish: pulping, plastic products, wood preserving, detergent, fungicide, plywood gluing, detergent solvents, bleaching, and metal finishing wastes. Large mortalities of the eggs and fry of chinook salmon in a hatchery were reported (118). Analyses indicated that the hatchery water contained 0.110 p.p.m. zinc and 0.060 p.p.m. cadmium which had leached from the galvanized hatchery trays. In 1953, Alabama biologists (113) made surveys of streams that had been poisoned by cotton insecticides in 1950. None of the streams had a great variety of aquatic invertebrates and none had desirable fish populations. Three of these streams had no game fish species at all.

Popp and Bahr (191) reported that *Daphnia* is very sensitive while fish are not as sensitive to cyclohexachlorhexane.

Hemphill (110), using 0.1 p.p.m. of toxaphene, killed all carp in a lake within 72 hr. Insect life was severely affected. Toxaphene breaks down in alkaline water and it was found that lakes with water of pH 8.0 and higher could be replanted with fish within four weeks. Bandt (21) discusses the effect of organic wastes on fish. The resulting oxygen depletion of the water often kills fish and the increase in sew-

age organisms adversely affects the fish food supply. The toxic effects of inorganic wastes containing metals, cyanides, and ammonia are mentioned. Substances known to affect the taste of fish are phenols, naphthenic acids, Kraft waste resins, higher aldehydes, unsaturated hydrocarbons from synthetic rubber plants, and aromatic nitro compounds from ammunition factories.

Death of carp in water draining from sewage irrigated fields occurred when a high pH coincided with a high concentration of ammonium compounds in the water. The ammonium was the product of decomposition of protein in sewage and the high pH was caused by the mass development of phytoplankton (205). Eustis and Hillen (90), in studies of the effects of Granby Dam on the Colorado River, indicate that deposition and accumulation of sediment may cause a marked change in species of insects present. The Mersey River Board (161) reports on the survey data from several streams of the area. In the first and second annual reports of the Trent River Board (235) (236) information is given on pollution, pollution abatement, water resources, land drainage, fisheries of the region, and effluent standards. The use of domestic and industrial waste waters for agricultural purposes, the different requirements of agriculture and fisheries in the use of such waters, and the value and risks involved, are discussed by Willer (260). Vivier (247) discusses research, waste treatment methods, and pollution legislation in England. An historical discussion of pollution abatement efforts during the past 100 years in England is presented by Pentelow (186). The The handbook of the Anglers Cooperative Association (11) discusses legislation relating to pollution of surface waters, its effects on riparian owners, and precautions they may take. Laws concerning the general conditions for discharge of industrial wastes, especially physical and chemical standards, were put into effect in Belgium by royal decree (164).

Liebmann (144) reported on investigations into the practical use of the saprobic system in estimating pollution loads and effects. Stundl (221) stresses the importance of studying fish populations and the uses of biological methods for classifying sewage polluted streams. In England, the Ministry of Housing and Local Government (165) is discussing standard procedures and studying the practicability of using toxicity to fish as one of the tests for effluents discharged into streams.

The Schuylkill River in Pennsylvania (17), which was polluted very badly with coal washing wastes, has recently been cleaned up and some areas have been stocked with fish. Neale and Eldridge (173) suggest that water quality may be seriously impaired by improper watershed protection. Lumbering, mining, gravel operations, improper grazing and other agricultural practices, railroads, hydroelectric power development, and flood control projects may contribute damage. Measures are urged to overcome this damage by proper watershed management.

In general, fish in polluted water are heavily parasitized. Fischtal (94) suggests that the fish are weakened so they are more susceptible to attack and, further, pollution may favor the development of intermediate hosts and thus increase the certainty of the parasite finding the next host. Tarzwell and Gaufin (226) point out some of the possible effects of polution on aquatic life and indicate environmental conditions which should be noted in stream surveys. Pertinent comments are made on the use and value of biological indicators of pollution and on the procedures for collecting and evaluating survey data. Communities of organisms typical of the zones in a polluted stream are described and

plans for a mobile biological laboratory are presented by Liepolt (145). A series of publications by the Limnological Station of the Lower Rhine (243) contrasts conditions in streams and lakes resulting from pollution, sets forth the part to be played by limnological research in national and international problems of water supply and the maintenance of satisfactory conditions, and deals with the distribution of zooplankton.

Cooke (61) reports a new study of the fungi in polluted water. Gennerich (102) summarizes the existing knowledge on nutrition and occurrence of sewage fungi with special reference to *Leptomitus* and *Sphaerotilus*. Slime-forming bacteria and filamentous blue-green algae were found to be abundant in petroleum refinery waste systems (68). Bruce (47) describes changes in the fauna of the estuaries of two New Zealand rivers due to domestic and industrial wastes.

Dangers in the disposal of toxic wastes at sea are brought out by Hjorth (116), who reports that some war materials were taken in the nets of fishermen and that there were several outbreaks of food poisoning from cod-roe contaminated by mustard gas from gas dumps in the Baltic.

Indicators of Pollution

Various types of aquatic organisms have been used as indicators of pollution. Brien (42) describes an apparatus for collecting diatoms from flowing streams and how they are used as indicators of the state of pollution in the stream. Wallace and Newman (249), in reporting on the condition of certain New Zealand beaches, indicate that pollution depends on the effects of wind and tide. With normal wind conditions the diatom count has some value as an index of pollution.

Mohr (168) states that for both fresh and salt water, a knowledge of protozoan ecology permits a qualitative indication of pollution by domestic sewage and effluents from food-processing plants, but other invertebrates have proved more popular as indicators of trade waste waters containing toxic substances. Weimann (254) contends that macroscopically recognizable organisms are more easily examined and more valuable in examination of rivers than microscopic organisms. Thienemann (228), in a monograph on chironomids, discusses these organisms as nuisances in water supply reservoirs and distribution systems, as indicators of organic pollution, and as inhabitants of filter beds of sewage treatment plants. Lackey (132) feels that a study of microorganisms as indicators of particular types of wastes offers great possibilities.

The complete stabilization and clarification of raw sewage in an open channel, 8 to 20 ft. wide and 4 to 24 in. deep, occurred over a 6-mi. course, with large white masses of protozoa being present in the zone of most active stabilization (188).

Turoboyski (238) made a study of infusoria as indicators of pollution in the Vistula River below Cracow.

Stammer (215) studied the effect of H_2S and NH_3 on 14 indicator organisms representing insects, annelids, turbellaria, protozoa, and all saprophytic classes. In the absence of D.O. all the protozoa were equally affected by H_2S. Reactions of the other organisms to H_2S follow the saprophytic classification. All the organisms reacted to NH_3 according to this classification excepting two oligosaprophytic insect larvae. These were relatively resistant to both H_2S and NH_3 as long as D.O. was present.

Effects of Water Quality

The changes in such water quality characteristics as temperature, D.O., CO_2, and pH were studied both from the standpoint of tolerance by aquatic life and their effect on the toxicity of various polluting materials.

The upper lethal temperatures (50 per cent of fish dead in 24 hr.) for 14 species of fresh-water fish are reported by Black (32). The temperatures varied from levels of 22° to 24° C. for salmon fry and fingerlings to 35° to 36° C. for carp and catfish. Degree of acclimatization to these temperatures had some effect. Brett (41) describes methods of testing for lethal temperatures and reports levels of 23.8° to 25.1° C. as the maximum for exposures of one week for young Pacific salmon. Sullivan and Fisher (222) made tests in which speckled trout (*Salvelinus fontinalis*) were free to move in water with varied temperatures of from 1° to 24° C. and allowed to select their own level. The selected temperature rose in the early part of the winter. Hart (109) made a study, at different geographical locations, of variations in the lethal temperature and diagnostic morphological characteristics of 10 species of fresh-water fish. With minor exceptions no evidence was found of a relation between lethal temperatures and morphological characteristics. Only 4 of the 10 species showed any appreciable difference with difference in geographical location.

The mean oxygen concentrations lethal to trout and bass at several different temperatures were determined (50). For brook trout, the mean lethal concentration at 55° F. was 1.59 p.p.m. and 2.54 p.p.m. at 70° F.; for brown trout, 1.42 p.p.m. at 49° F. and 2.53 p.p.m. at 69° F.; for rainbow trout, 1.05 and 1.10 p.p.m. at 52° F. and 1.82 p.p.m. at 71° F. For smallmouth bass, the mean lethal D.O. at 52.5° F. was 0.63 p.p.m., and at 80° F., 1.08 to 1.15 p.p.m.

Studies at Oregon State College (172) to determine the effect of low oxygen tensions on silver salmon, *Oncorbynclius kistutch,* at different temperatures, showed that young silver salmon could withstand dissolved oxygen levels below 3 p.p.m. within a temperature range of 12° to 24° C.

For most species of fish, the critical concentration of D.O. is higher in summer than in winter (194). The critical concentrations of D.O. for six species of fish at various summer and winter temperatures are given. Duijn (82) discusses the importance of the concentrations of D.O. and CO_2 for the survival of fish. The minimal oxygen requirements and the amount of oxygen consumed per unit weight of fish at the various temperatures are given for salmonids, coarse, and tropical fish.

The eggs of rainbow trout had a low oxygen requirement during the first stages of segmentation, but the requirement increased rapidly with the beginning of gastrulation (80). In water low in D.O., the second-stage gastrulation failed to take place.

In fish kept in sea water with a gradually decreasing D.O., no change in heart muscle glycogen occurred until the oxygen content fell below 3 cc. per l. (normal for sea water, 6 cc. per l.) The glycogen content then decreased progressively as the oxygen decreased. At death from anoxia, the glycogen content had decreased to about 75 mg. per 100 g. (normal 1,150 mg. per 100 g.) (64).

Byrd (53) found that during periods of thermal stratification in farm ponds the greatest numbers of fish occurred in shallow waters and they were unable to live in water where D.O. was less than 0.3 p.p.m. and the CO_2 content was 4.4 p.p.m. or more. Bhaskaran (30) reports the possibility of a large-scale mortality in fishes when organic manures are added to fish ponds, due primarily to the effect on the oxygen balance.

Alikunhi *et al.* (5) described a mortality of carp fry in water supersaturated with dissolved oxygen, while Costin (66) reported a fish kill caused by an oxygen-depleting waste. Olivier *et al.* (178) reported that free cercariae of *Schistosoma mansoni* died rapidly when deprived of oxygen, but that those in the snail can survive without oxygen. Fox and Sidney (98)

showed that with decreasing concentrations of oxygen there was an increase in respiratory movements of caddis larvae.

Seasonal variations in the number of fish present in a channel carrying the effluent of a sewage works seem unrelated to the chemical changes in the effluent (6) (252). Laboratory studies indicate that the precise level of oxygenation of a contaminated water is of great importance. In further studies with ammonia, it was found that the toxicity of solutions of ammonium salts depends on the concentrations of unionized NH_4OH and NH_3. Survival of trout in a given concentration of undissociated NH_3 increased markedly with an increase of D.O.

Downing (81) found that the survival times of rainbow trout in concentrations of KCN in the range of 0.105 p.p.m. increased with the increase in D.O. between 10 per cent and 100 per cent of saturation. The effect was most marked in the lower concentrations of CN.

In an experimental study on the influence of CO_2 on the utilization of O_2 by some fresh-water fish (34), it was found that the O_2 content was higher at death in tests where the CO_2 tension was increased. When CO_2 tension was low, the oxygen left in the water at the death of the fish was 4 mm. Hg for brown bullhead, and 19 mm. Hg for brook trout. The CO_2 tensions causing death when a tension of 160 mm. Hg of O_2 remained in the respired water ranged from 80 mm. Hg for blacknose shiner to 338 mm. Hg for brown bullhead.

The pH tolerance of the bluegill in buffer solutions and in a constant-flow apparatus was tested (232) with a single acid or base. The pH tolerance limits found in the constant-flow apparatus were 4.0 in HCl and 10.35 in NaOH. Vivier (246) claims that pH less than 4.0 and greater than 9.5 can be lethal to the fauna of a stream. The injurious action is due either to the presence of dissociated H and OH ions or to a toxic action peculiar to the substance. Use of pH in field studies is often helpful in disclosing the nature and extent of pollution.

Waede (248) found that the flounder is more resistant to changes in salt concentration and temperature than is the sole. There is no difference in their resistance to quinine and ethyl alcohol. Halsband (107) correlated the reactions and adaptations of fish to various external influences. He related respiration with temperature, pH, salt concentration, and oxygen content of the external medium. He also studied the frequency of respiration in solutions of urethan, chloral hydrate, quinone and after x-ray exposure.

Hiatt *et al.* (115) tried to correlate the chemical structure of 500 compounds with the degree and type of irritation they caused in fish. Nitro and nitroso compounds, certain halogenated organics, disulfides, and quinones all irritated fish by inhibiting the sulfhydryl groups in the chemical sensory systems.

Guppies of both sexes kept in water containing initially 200 c. per l. of P^{32} for periods up to 150 days were rendered sterile (245).

Bioassays and Toxicity

Laboratory studies of the toxicity of many materials to aquatic life were reported.

Wuhrmann *et al.* (263) briefly outline procedures and methods to be followed when conducting bioassays with fish. They propose a 6-hr. bioassay period and discuss the choice of fish, size of fish, acclimatization, number of fish per test, and manifestations of toxicity. Saila (203) investigated the effects of varying the volume of toxicant solution, aggregation, temperature, and change in condition of the test animal upon results of bioassays. In spite of relatively favorable experi-

mental conditions, it seems that estimates of relative toxicity using fish are affected by uncontrolled variations which may limit the dependability of results.

Anderson (9) discusses the use of *Daphnia magna* for bioassay procedures and how changes in water quality may affect industrial and biological uses. Allan *et al.* (6) suggest the use of floating live boxes to confine fish at fixed points in an industrially polluted stream. They indicate that the absence of fish in the effluent during the winter may not be due to adverse chemical conditions, but that many migrate to other places and return in the spring.

Vernon (244) reviewed the literature on the toxicity of copper, lead, and zinc to fish. Among subjects discussed were the effects of heavy metals on fish, toxicity levels, and the effects of water chemistry on the toxicity of these metals. Trama (233) using bluegills as test fish, found the 96-hr. Tl_m for Cu was 0.74 mg. Cu per l. and the 48-hr. Tl_m was 0.90 mg. Cu per l. Toxicity is due to the Cu ion and is independent of the anion.

The decline in the salmon fishery in the Pacific Northwest is correlated with heavy sulfite waste liquor (SWL) production (261). The following mortality threshold for salmon in SWL at various ages were determined: For chinook salmon 38 days old, 1,175 p.p.m.; 280 days old, 600 p.p.m.; 305 days, 560 p.p.m.; for pink salmon 102 days old, 1,550 p.p.m.; 198 days, 530 p.p.m.; silver salmon 351 days old, 1,230 p.p.m.; 412 days, 1,015 p.p.m. Marine food organisms are less tolerant to SWL than young salmon.

Rainbow trout were placed in 1/220 M solutions of ammonia, hydroxylamine, hydrazine, and mono-, di-, and trimethyl amine, and their activity was measured (65). Fish were most active for prolonged periods in the presence of hydroxylamine and least active in the presence of NH_4OH.

Acrylonitrile breaks down in water to yield HCN. The lower tolerance limit to fish is about 20 to 25 p.p.m., whereas 100 p.p.m. will kill in about 24 hr. Acrylonitrile is also toxic to crustacea and aquatic insect larvae (20).

Turnbull *et al.* (237) determined the Tl_m of bluegills to 20 c.p. chemicals and to 14 industrial products and petroleum refinery wastes.

Gas liquor containing 2,600 p.p.m. phenol even when diluted 600 times was lethal to trout in 12 hr. *Gammarus*, *Tubifex*, and chironomids were not affected (146). The minimum lethal dose and the time of survival of five species of fish belonging to the sunfish family in seven preparations used in oil well drilling operations was determined by Anderson (8). Caustic soda, white lime, and oil well cement were most toxic.

LeClerc *et al.* (137) believed that fuel oil and lubricating oil caused the death of fish by preventing the reoxygenation of the water. Bioassays indicate that fuel oil has some toxicity. The minimum lethal doses of some detergents and soaps in distilled and tap water are given and symptoms of poisoning are described (138). Soaps were more toxic in distilled water than in hard water. With most detergents the type of water has little effect on their toxicity. Minimum lethal concentrations of various detergents varied from 2 to 20 p.p.m. For the soaps, the minimum lethal concentrations ranged from 10 to 12 p.p.m. in soft water and from 250 to 1,000 p.p.m. in hard water.

Sacha (202) found that fish and arthropods were more sensitive than bacteria to benzene and benzene hexachloride. In saturated solutions, protozoa and algae were killed almost instantly and fish were injured in 1 to 4 min. Bervoets (29) controlled blackfly larvae with a single dose of benzene hexachloride (3 p.p.m.) There was no change in the number and kinds of

plankters in the stream after treatment. In laboratory tests, a toxic effect was observed only when the concentration exceeded 30 p.p.m.

When the water in the river Pleisse contained 20 p.p.m. phenol and 0.0 p.p.m. D.O., no life existed (26). When the D.O. increased to 5.3 p.p.m. and phenols decreased to 4.3 p.p.m., protozoa and algae appeared and increased in variety and quantity as the phenols were reduced to 0.2 p.p.m. In laboratory experiments, river protozoa tolerated phenols and cresol up to 300 p.p.m.; pyrocatechol, 150 p.p.m.; resorcinol, 600 p.p.m.; phloroglucinol, 650 p.p.m.; pyrogallol, 33 p.p.m.; and hydroquinone, 6 p.p.m. Increasing the temperature increased the toxicity.

Vallejo-Friere *et al.* (240) found that concentrations of quaternary ammonium compounds that kill cyprinodont fish within 1 hr. will kill *Australorbis* snails within 24 hr. Jakoski (121) found that the various synthetic detergents showed a varied molluscicidal activity against *Stagnicola reflexa*. No correlation between chemical structure of the detergent and toxicity could be shown. An anionic alkylarylsodium sulfonate was most toxic. The toxicity of 32 inorganic and organic mercury compounds to molluscs was determined (39). Thirteen organic mercurials at concentrations of 1 p.p.m. were 90 to 100 per cent effective against *Australorbis glabratus*. At 0.3 p.p.m. isopropylmercuric thiocyanate and phenylmercuric acetate killed 90 per cent of the snails.

Wilkinson (259) reports minimum lethal concentrations of sulfides as sodium sulfide at 3.0 p.p.m., mercaptan at 0.5 p.p.m. as methyl mercaptan, resin acid fraction of soap (Na salt) at 5 p.p.m.

In experiments to control molluscs, Wright and Dobrovolny (262) report on the efficiency of 33 compounds. In stagnant water the most effective molluscicides were pentabromophenol, pentachlorophenol, sodium and copper pentachlorophenates, bis (3,5,6-trichloro-2-hydroxyphenol) methane and its sodium salt, and phenyl mercuric acetate. These compounds in a concentration of 10 p.p.m. killed 99 to 100 per cent of snails, and most were effective in a concentration of 2 p.p.m.

D.D.T. and Hexa were confirmed to be strong fish poisons (167); in aquaria the quantity normally used for fly control is absolutely lethal to aquarium fishes.

Werner (256) reports treatment with thiouracil to have some effect on German brown trout eggs and fry.

McGraw (155) reports that the bacterium causing furunculosis of fish survives longer in polluted water and that the degree of infection increases with the quantity of pollution.

Fjeringstand (96) found that *Daphnia magna* could not survive in sewage in which ammonia was demonstrable.

Nietzke (176) investigated the effect on fish of hormone weed killers. Di- and trichlorophenoxyacetic acid differed in their action on fish, with the greatest damage caused by mixtures of the two. Emulsifying agents harmed fishes by attacking the mucous membranes and gills.

The addition of CO_2 to a lethal ammonia solution markedly reduced the toxicity of the solution to rainbow trout. The CO_2 decreased the pH of the solution and increased the ionization of the NH_4OH (4). The toxicity of the chloride, sulfate, and nitrate salts of Na, K, and Ca to the bluegill was determined (234). The relative toxicity of the cations was $Na < Ca < K$. The relative toxicity of the anions, based on experiments with the sodium salts, was $Cl < NO_3 < SO_4$.

In the first addendum to "Water Quality Criteria" (157) McKee briefly reviews some recent publications on the toxicity of pure substances and industrial wastes to fishes and other aquatic life. These works are especially valuable for the arrangement of

references according to subjects and the complete bibliography.

Bacteriology

Only 11 outbreaks of disease were reported (73) in 1953 for which epidemiological investigation or laboratory test indicated that water was the vehicle of infection. In one outbreak, two cases of typhoid fever in the same family were attributed to swimming in a river. Two outbreaks of infectious hepatitis were associated with cross-connections of water supply and sewage disposal. No outbreak was reported in which a city water distribution system was at fault.

Sewage disposal, water supply, and gulls have been implicated in the spread of *Salmonella* to humans in Ketchikan, Alaska (12). Gulls became contaminated while scavenging along shoreline areas where outfall sewers discharge, and later polluted the community's surface-water supply. Cultures of organisms from gulls and from two hospitalized patients with gastroenteritis were identified as the same species. Broek *et al.* (45) has reported the contamination of polder water (Netherlands) with *S. paratyphi* owing to the influx of sewage, although neither the origin nor the reason for the contamination was discovered. A waterborne epidemic of *S. paratyphi* infection (22) occurred in a small town in Slovakia where many inhabitants obtained water from a stream. Thiele and Brinkmann (227) presented the results of a study to determine the most suitable method of detecting *S. typhi* in water and to develop a reliable procedure also suitable for the bacteriological examination of sewage and polluted surface waters. Best results were obtained with Lovrecovich's modification of Wilson and Blair's bismuth sulfite medium, which strongly inhibited accompanying bacteria but permitted easy recognition of *S. typhi* and certain other *Salmonellae*.

Jensen (122) examined the sewage from five towns with tuberculosis sanatoria and from one institution for the care of feebleminded which had a tuberculosis ward. These six effluents were treated in biological purification plants. Tubercle bacilli were demonstrated in the influent to all the plants and in the digested sludge of all those receiving sewage from areas having a ratio of one infected person to 600 or less uninfected people. From 11½ to 15 months were required before tubercle bacilli could no longer be demonstrated in the sludge kept on the drying beds. The addition of 10 mg. of chlorine per liter of effluent from an activated sludge plant was found effective in destroying tubercle bacilli.

An explosive exacerbation of a poliomyelitis epidemic in Edmonton was described by Little (147). The series of events associated with the epidemic provided circumstantial evidence and epidemiologically suggested that the outbreak of poliomyelitis was waterborne.

Melnick *et al.* (159) (160) have found that the gauze pad method yielded a significantly higher percentage of positive tests for Coxsackie viruses from sewage than the grab sample method. Of 1,929 samples of urban sewage examined from six states, 269 samples yielded Coxsackie viruses. In almost every urban area studied, viruses appeared in some of the specimens collected in the summer and fall, and disappeared during the winter and spring.

In an investigation to determine the efficiency of primary sewage treatment plus chlorination on the removal of animal parasites, Wang and Dunlop (250) found that approximately 20 per cent of the *Ascaris* ova and 46 per cent of the *Endamoeba coli* cysts in the raw sewage were still present after treatment. Cysts of *Endamoeba histolytica* were not found in either raw or treated sewage. The M.P.N. of coliform organisms and enterococci showed

a decrease of more than 99 per cent during the same treatment.

Cooke (60), in a study on the use of antibiotics in media for the isolation of fungi from polluted water, recommended use of chlortetracycline in modified Waksman mold agar media.

Cooke (61) reviewed the literature on fungi in polluted water and sewage. In a comparative study of media for the enumeration and isolation of fungi, he found that an altered Martin's modification of Waksman's soil mold plate count agar to be the most efficient. Of 105 mold species isolated from a polluted stream, only 6 were present in all samples examined and only 48 were found in four or more of the eight stations studied.

Sewage fungi (143) can grow free of attachment in large deep rivers. With increasing age (i.e., distance from the outfall) of the *Sphaerotilus* flock the following organisms occur: cocci and bacilli, flagellates, ciliates, fungus *Apodya lactea* and *Beggiotoa alba*. As the flock slowly disintegrates *Glauconia scintillans* and *Lionotus fasciola* occur abundantly. Thus the age of the flock can be determined from its biota. There is no vertical variation. In large rivers with strong turbulence, *Sphaerotilus* is not evenly distributed and most of it is found on the river bottom. The quantities of wet fungus per cross-section per day were measured.

Painter (181) studied the nitrogen, vitamins, and trace elements requirements for the growth of four fungi found in trickling filters.

Surface stones from three positions on a trickling filter were examined by Hesseltine (112) at monthly intervals for a year. The filters received miscellaneous chemical wastes and large amounts of antibiotic production wastes. Three species of fungi were found at all times and were considered the only species regularly inhabiting the filters. Other species observed were considered chance contaminants.

Morris and Weaver (171) determined the coliform and streptococci M.P.N. for duplicate samples of well water. One sample was examined immediately after collection and the other after 24-hr. storage at room temperature. Coliforms and streptococci were deemed to be of equal value as index organisms for detecting the presence or absence of pollution. In their opinion the tests for streptococci required less time and materials than the tests for coliforms. Gilcreas and Kelly (104) investigated the significance of the coliform test in relation to intestinal virus pollution in water. They studied the survival of coliform organisms in water and sewage in comparison to *E. coli* bacteriophage, Coxsackie virus, and Theiler virus when subjected to heat, chlorine, and ultraviolet light. Except for storage in the cold and weak chlorine doses, water treatment which destroys coliform bacteria can be counted on to destroy viruses as well. Stuart (220) stated that bacteriological examinations do not provide an absolute answer to suitability of water for human consumption, but must be supplemented by sanitary survey. The Engineering Section, Missouri Basin Health Council (207), has adopted criteria to guide the pollution control programs in the basin.

Macdonald (151) reviewed the bacteriological data of the water from the Mississippi River near New Orleans. He concluded that monthly averages of the M.P.N. are not suitable and recommended use of monthly median or geometrical means.

In a laboratory study of the efficiency of water treatment processes, Metzler *et al.* (162) showed that settling of either natural turbidity in a water or an alum floc concentrated a majority of the *H. capsulatum* spores in the sediment, and that model rapid sand filters did not effect complete removal of either the yeast or the mycelial phase of *H. capsulatum* suspended

in water. Experimental results indicated minimal effective contact times of 4 hr. with 0.35 p.p.m. free chlorine and 35 min. with 1.8 p.p.m. free chlorine. Ritter (198) and Cooke and Kabler (62) have reported survival of *H. capsulatum* in excess of 100 days in sterilized tap water and Ohio River water at 4° and 20° C.

At summer temperatures, few *E. coli* will survive more than 8 hr. in Great Salt Lake water, but at 6° C. approximately 50 per cent will survive 24-hr. exposure (100). Angelillo (10), using mineral (alkaline bicarbonate type) waters of Sardenia, found that *E. coli* survived as long as 28 days at room temperature. In experiments by Buttiaux and Lewis (52) approximately 50 per cent of *S. typhi, S. paratyphi B,* and *S. enteritidis* survived 44 hr. in North Sea water at 18° C.

Bringmann (43) (44) compared the action of ozone and free chlorine in drinking water and reported that ozone destroyed bacteria of the coli group much faster with a relatively smaller amount of gas and in a shorter time. Morris *et al.* (170) have described the composition of water-soluble tablets for disinfection of drinking water under field conditions. Such tablets will dissolve in less than 1 min. at room temperature, liberating 8 mg. of elemental iodine per tablet and will satisfactorily treat 1 l. of most natural waters within 10 min.

Levin and Laubusch (141) examined the water from 299 Pullman cars by "Standard Methods" fermentation tube test and a membrane filter technique, and obtained comparable results. In a report of a field study of the Standard Methods Committee for the Examination of Water and Sewage, Kabler (126) compared the results of 1,706 water samples examined simultaneously by the membrane filter and "Standard Methods" M.P.N. procedures. The results of the two methods were compared on the basis of the 95 per cent confidence limits of the confirmed M.P.N. On this basis, results of 73.8 per cent were in agreement. Of 650 samples having a coliform content in the range associated with potable waters, 88 per cent showed results in agreement by the two tests. Jeter *et al.* (123) studied type differentiation of coliform organisms with the membrane filter technique. They found that from 92 to 95 per cent of coliform organisms growing on the membrane filter develop a characteristic "metallic" yellowish surface luster and subsurface color, and that the great majority (95 per cent) of colonies that do not develop sheen and color are not coliform organisms as defined by "Standard Methods." Hajna and Damon (106) have described a new membrane filter procedure for the detection of coliform organisms in water by a single-step technique. Broscheit and Zimmermann (46) compared the results of tests on 600 samples of water of varying quality and found no reason to recommend the substitution of membrane filter for the titration method. In a comparative study of the membrane filter with the M.P.N. method of enumerating coliform organisms in water, Shipe and Cameron (212) found a significant difference in the recovery of organisms by the two procedures, the recovery by the MF technique being low. This difference was explained by the accumulation of toxic substances (copper and zinc) on the filters. In a comparison of the MF and M.P.N. techniques in examining sea water, Presnell, Arcisz and Kelly (193) concluded that the membrane filter method was a reliable technique for determining the coliform densities of sea water if due regard was given to water turbidities and bacterial densities in determining the volume of sample for filtration.

Chemistry

The interrelationship of microorganism and sulfur compounds is the sub-

ject of two papers of interest. Bryner *et al.* (49) concluded that most of the soluble copper and iron found in acid mine drainage from Bingham Canyon are the products of biological oxidation of sulfide minerals. Their work, incidentally, was directed at developing methods for the profitable leaching of low grade ores. Wheatland (257) considered the sulfur balance in a polluted estuary. Sulfates are reduced to sulfides biochemically in the absence of oxygen. The temperature dependence of the biochemical reaction is delineated. Formation of sulfate from sulfide is reported to be a chemical oxidation in the Thames estuary. The presence of iron and suspended matter catalyzes the reaction, which may be limited by the availability of oxygen. Flaigg and Reid (97) considered the effect of nitrogen compounds on stream growths.

Czensny (71) analyzed 28 sludge obtained from lakes and ponds in Germany for moisture content, pH, alkalinity, sulfides, phosphates, and humus.

Oxygen Sag and Self-Purification

Camp (55) commended a method for estimating stream self-purification capacity proposed by Churchill (57). Black and McDermott (35) discussed various factors affecting oxygen sag. Mueller (166) also considered factors related to oxygen sag and presented illustrative calculations.

Akerlindh (3) demonstrates mathematically the existence of proportionality in water pollution by devising an equation relating oxygen deficiency and bacterial density in a polluted water to the added load of oxygen demand.

Wiegand (258) presented a procedure for determining the constants of the well-known monomolecular B.O.D. formulation. The procedure suggested appears to be closely related to the "Thomas Slope Method."

The resistance of individual materials to self-purification has been considered in several papers. Ettinger *et al.* (88) investigated the persistence of pyridine bases in polluted waters and found these materials to be subject to complete biochemical destruction in short periods under favorable conditions. Furfural also was reported (89) subject to very rapid biochemical destruction, with the material also subject to vaporization loss and chemical oxidation. Kroner and Moore (130) reported lignin to be highly resistant to attack in polluted water, with very slow degraduation of the chemical reported under all conditions investigated. Mills and Stack (163) studied the biological oxidation of relatively concentrated solutions of a large number of chemicals in four groups: (a) synthetic chemicals readily oxidized biologically; (b) synthetic chemicals oxidized after an initial lag; (c) chemicals oxidized at very slow rates, with or without initial lag; and (d) materials which resisted biochemical oxidation for extended periods under the study conditions.

Surveys and Studies

Several articles concerned pollution of tidal rivers, estuaries, beaches, harbors, and lakes. Factors to consider in obtaining data necessary to estimate the waste assimilation potential of a tidal river were discussed by Laffey (133). Pollution of a sheltered harbor by cabin cruiser waste discharges was reported by Ingram and Diachishin (119). Health hazards to persons swimming in adjacent waters, as well as coliform densities exceeding those approved for shellfish waters, were found to exist. Moore (169) surveyed beach pollution at a seaside resort before and after installation of a new sewer outfall. The presumptive coliform count on samples of sea water was found to be a satisfactory index of contamination and the conclusion was reached that a large series of tests by a relatively simple technique is preferable to a more limited investiga-

tion by more complex methods. Bacteriological standards for bathing beaches are discussed. Orlob and Eldridge (179) describe the use of an underwater disposal line to disperse pulp mill wastes in a bay to prevent an oxygen deficient water barrier.

Ketchum and Keen (128) summarized the results of 385 hydrographic stations in the Bay of Fundy. It was found that the total quantity of river water accumulated in the Bay of Fundy is equivalent to the quantity introduced by rivers during a period of about 76 days. The exchange ratios for tidal excursion segments of the Bay of Fundy range from 0:17 near Cape Chignecto to 0.056 in the segment south of Grand Manan. It was calculated that the total accumulation of river water in Passamaquoddy Bay is equal to the quantity introduced by the rivers in about 16 days.

Ketchum (127) in a general review discusses the fundamental similarities in estuaries and a wide variety of detail in circulation which may be expected.

Stratification and overturn in English lakes and reservoirs and related water supply problems were discussed by Thompson (229). Cooley and Harris (63) wrote of the use of inflow jets to prevent stratification in reservoirs. Factors involved in disposing sewage effluents to lakes were discussed by Sawyer (204), particularly with regard to causing "biological explosions." Rice and Johnson (197) considered the general character of wind-generated waves and their possible effects on the mixing of wastes discharged to large bodies of water. It was concluded that waves produced by wind cause appreciable mixing and that wind blowing over a sewage field will cause a surface layer of the field to be translated at an appreciable rate in the direction of the wind.

A new automatic current float for studying rate and direction of movement in large bodies of water is described by Carruthers (56). This deep-riding buoy, after floating freely for a time away from a chosen liberation point, anchors itself, hoists a flag indicating it has done so, and registers the time at which its travel ceased. Construction details and drawings are given.

Several articles dealt with the condition of streams or effect of pollution on streams. Materials which could occur in a well-purified sewage effluent and yet might have adverse biological influence on a stream if little dilution were available are considered by Roberts (200). One of the conclusions reached is that the residues of detergents present in an effluent of an efficient sewage treatment process have not been modified in such a way as to remove their toxicity.

Wuhrmann (264) investigated the variations in the types and abundance of microscopic organisms on the bed of an artificial channel when receiving various dilutions of raw and treated sewage. Dilution of settled sewage to such a degree that detrimental effects on the oxygen balance of shallow, turbulent streams are excluded may still induce quite undesirable growths of heterotrophic river bed organisms (for instance, *Sphaerotilus*). The tests showed good correlation between river biocoenosis (river bed organisms) and the concentration of polluting matter in water measured by B.O.D., oxygen consumed from $KMnO_4$, and organic nitrogen. Equal concentrations of B.O.D., etc., in settled and treated sewage did not produce comparable associations of organisms, however. Curves are presented relating the biocoenosis of a stream and the B.O.D., oxygen consumed, and total N using settled sewage, low-rate activated sludge effluent, and high-rate activated sludge effluent. A chart also shows the dilution necessary to avoid heterotrophic organisms on the stream bed for sewage receiving various treatments.

Pillai *et al.* (188) describe the natural purification of sewage in an open channel in India in 4.75 mi. of flow. At the point of most active stabilization large white masses of protozoa were found.

Stoessel (219) writes of contamination of German streams by oil and lists possible waste sources. Detergents as pollutants in Kansas stream are the subject of a paper by Culp and Stoltenberg (69). Troubles in a water supply at Wheeling, W. Va., purportedly from detergents, are described (19). Hohle (117) describes the effect various pollutants have on the preparation of boiler feed water. Chlorides shorten the life of demineralizers. Organic pollution causes viscous deposits on the beds, and when high the distilled water contains CO_2 and NH_3. Organic pollution has effect on removing oxygen in degasifiers.

A final report on field investigation and research on waste-water reclamation and utilization in relation to underground water pollution was released (54). This study determined that a high degree of sewage treatment is necessary if the effluent is to be spread efficiently. Suggestions for the "conditioning" of the soil, both initially and at six-month intervals thereafter, are made. Evidence is offered that the practice of spreading can be bacteriologically safe. The report also cautions that two other nuisances besides pollution must be guarded against: the spreading pond can be responsible for mosquitoes and algal odors.

A report (91) on the quality of surface waters east of the Mississippi includes a bibliography of published and unpublished analyses of the surface waters. The polluted condition of the Holston River in Tennessee was reported as preventing new industries from being attracted to the area (14).

A rapid method for estimating stream pollution caused by spent sulfite liquors is proposed by Kleinert and Wincor (129). This method involves the determination of lignosulfonic acid by the lycosine technique and use of the potassium dichromate oxygen consumed test.

Cleary (58) discusses a project underway to make a comprehensive literature survey of toxicity in the water supply and sanitation field. The information is being prepared on punch cards for easy reference.

Abatement and Control

The effects of river developments for water supply, hydroelectric power, navigation, and flood control purposes on stream self-purification capacity have been discussed by Velz (241). Poor location and/or operation of such facilities can result in greatly reduced waste-absorbing capacity of the stream. Velz has emphasized the desirability of multiple-purpose developments, one important purpose being low flow regulation to increase the capacity of the stream to handle deoxygenating wastes. Ahlgren *et al.* (2) have reported trends of current thought regarding multiple use of watersheds and water supplies. Views of water supply engineers, recreation departments and consumers are reported.

Davidson and Churchill (74) discussed the relationship of stream regulation and stream pollution. Storage has a profound effect on the assimilation of pollution in the reservoir. Regulation of flow may have beneficial or detrimental effects on the various downstream uses of the water.

Black and Devendorf (33) presented the problem of industrial pollution of international boundary waters along the Niagara area.

Cohn (59) has reported the recent appropriation of $2,000,000 by the Pennsylvania Legislature for partial repayment to municipalities of the costs of pollution abatement measures. Progress on pollution abatement in Indiana was reported by Poole and Holtje (190), who indicate improvement of 1,000 mi. of Indiana streams

as against 500 mi. still considered polluted. The Indiana program has been, briefly, to prevent new sources of significant pollution, to locate and eliminate existing major sources, and to make reasonable and economic use of the natural self-purification capacity of streams insofar as feasible.

A report on the Missouri River Basin Compact has been given by Schwob and Hopkins (207). Ten states are involved. Desirable stream criteria, and the present inadequacies of waste treatment facilities, are discussed.

Dechant (76) has described the effectiveness of the reclamation program for the Schuylkill River in Pennsylvania. As a result of dredging and enforcement of the State Anti-pollution Law the once-foul river has been vastly improved and is now available for recreational uses (17). Sewage treatment at Roanoke, Va., has resulted in marked improvement of the Roanoke River (101). The California Central Valley Regional Control Board has adopted a strict anti-pollution policy for the Sacramento River (15). The minimum dissolved oxygen requirement for the entire length of the River is 85 per cent of saturation.

Dworsky (83) has indicated that one of the basic factors controlling the development and location of new industry will be the availability of water, with respect to both quantity and quality. The need for integration of all water operations and uses for most efficient use of the nation's water resources has been stressed by Watson (253). There is lack of agreement regarding stream standards and acceptable pollution loading, leading to confusion and inefficient utilization of available water. Watson has also called for equipment for automatic, continuous recording of water quality and for more adequate training in pollution abatement.

Pirnie (189) stressed the necessity of eliminating in advance industrial wastes which, if discharged to a stream, might affect human health. He discussed a number of wastes in terms of their effects on safety and palatability of drinking water, recreational uses of the stream, and quality of water available to downstream industrial users. The suggestion that industries pool their money to combat pollution has been made by Stanley (216); Berry (28) has indicated a need for better operation of waste treatment facilities.

Efforts of one industry to eliminate discharge of cyanide wastes have been described by Barr (23). Under order of the State of Indiana, cyanide wastes were eliminated by a process change, but this created an oil wastes problem. The latter was solved by the use of separators and an infiltration lagoon. Wastes from the American Cyanamid Company are being studied in a pilot installation to determine design factors for the Somerset-Raritan Valley Sewerage Authority in New Jersey (13).

Operation of a $500,000 waste treatment plant by the Koppers Co. has been started at Follansbee, W. Va. (18). This installation was preceded by six years of research, and the process is designed to accomplish better than 99 per cent removal of phenolic wastes.

The dangers inherent in reclaiming sewage and industrial wastes have been discussed by Bush and Mulford (51), who indicate that there are some 200 locations in California where waste waters are utilized. Pickett (187) has discussed the problem of pollution of ground waters, and has urged that it be stopped. Brune (48) has indicated that high sediment concentrations represent one of the important forms of stream pollution, and has discussed this problem in terms of types and extent of damage, sources of harmful sediment, and remedial measures.

A discussion of legal problems and decisions with respect to water rights and uses in Michigan has been presented by Billings and Booth (31), who note that the Michigan law is

contained in decisions of the State Supreme Court, rather than in acts of the legislature. Recent higher court decisions on wastes cases in several states have been reported and discussed by Parker (182). The cases included questions as to (a) special assessments on property located outside of a lawfully created sewage district, (b) the sewage district as a separate tax entity regardless of whether its geographical limits coincide with those of a city, and (c) liability of individuals for removal of materials from the bed of a navigable stream. The Connecticut Supreme Court of Errors has upheld a decision of a Connecticut trial court extending the time within which a defendant (the City of Norwich) was required to comply with an order issued by the State Water Commission (16), holding that the change in dates did not make a material change in the order of the Commission.

Stream Standards

The recent literature considers some of the major factors which affect the choice of stream standards in specific situations, and indicates the unsuitability of rigid standards designed for general application to all streams and locales within a large area. Participants at the 1953 Industrial Wastes Forum (36) were generally agreed that standards should be selected on the basis of most beneficial stream use. Waste disposal was indicated to be one of the legitimate uses of a stream, and the natural self-purification capacity of a stream is an economic asset which should not be wasted. The discussion also indicated the need for separate thorough study of the factors involved in each individual situation, since no two cases are identical. Kittrell proposed classification of individual stream stretches rather than entire streams, on the basis of most beneficial use, a device which has been successfully applied in the past and which has considerable merit.

Hess (111) and Leclerc and Beekmans (139) have emphasized again the need for consideration of the natural self-purification capacity of a stream as a factor to be weighed in setting standards. In reviewing the British Rivers Act of 1951, Roberts (199) has indicated a need for modification of its general B.O.D. effluent standard so as to allow for the high reaeration capacities of shallow streams and the dissolved oxygen content of sewage effluents. Towne (230) has reviewed the development of water quality criteria, and emphasized the growing demand for water which can be re-used. Viewed in this light, he has indicated the need for stream standards which are sufficiently flexible to accommodate future changes in social and economic conditions.

Sharpe (209) has noted the water quality criteria adopted by the International Joint Commission on Pollution of Boundary Waters and recommended by the Pollution Control Board of Ontario for lake and river waters used as sources of domestic water supply. He indicates that these criteria would generally require waste discharge quality of (a) 20 p.p.b. or less of phenol equivalents, 17 p.p.m. or less of iron, and 15 p.p.m. or less of oils as determined by extraction; (b) pH between 5.5 and 10.6; (c) treatment for removal of bacteria and odor-producing, toxic, and deoxygenating substances. It is also noted that better waste discharge quality might be necessary in some cases. Nesmeyanova (175) has reported the following odor threshold limits for various phenols and their respective chlorophenols:

	Phenol	*Chlorophenol*
PhOH	25 p.p.m.	0.001–0.0005 p.p.m.
Cresol	0.0025	0.001–0.0002
Thymol	0.05	0.05
Resorcinol	40	No odor noted
Hydroquinone	No odor noted	No odor noted
Creosote	0.125	0.01
Naphthol	7	0.5

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Significant Trends and Summary

The increase in the number of references included in the review under the various sections is apparent from the following:

	1954	*1953*
Analytical methods	100	64
Sewage	212	166
Radioactivity	116	59
Industrial wastes	258	191
Water pollution	264	256
	950	736

It is difficult to summarize the mass of information that is included in this review. However, certain general and significant trends and developments might be pointed out briefly, as follows:

1. The demonstration that chlorate oxygen is available for biochemical oxidation and thus, by measuring the increase in chloride which is the product of the reduction of chlorate, an alternative method for B.O.D. can be developed.

2. Continued investigations on the B.O.D. of pure compounds and the importance of seeding with appropriate acclimatized cultures for the establishment of proper B.O.D. values.

3. The demonstration that in nitrification the rate of oxygen uptake is independent of the amount of the primary oxidizable material (ammonia) and, therefore, at least this type of oxidation if not a first-order reaction, but the rate is related to the number of nitrifying bacteria.

4. Continued interest in evaluating pollution, either by over-all chemical oxygen demand methods or by analysis for specific chemical compounds, such as detergents and other specific compounds found in wastes.

5. Concerted efforts by a number of investigators on methods for determining D.O. by electrometric methods and for continuous automatic recording.

6. Development of methods for determination and differentiation of various forms of residual chlorine.

7. Considerable effort has been manifested in elucidating the mechanism of aeration and attempts have been made to increase the aeration efficiency in order to allow higher loadings in the activated sludge process.

8. Study of the physical, chemical, and biochemical effects of detergents on sewage treatment processes continues, with particular emphasis on the problem of frothing in activated sludge plants.

9. Some differences of opinion exist in regard to the future of high-rate digestion, which several investigators have shown to be feasible on the basis of laboratory, pilot, and full-scale experiments.

10. Additional negative evidence has been reported as to the value of biocatalysts in promoting biochemical activities in sewage treatment processes.

11. The advantages of thickening raw sludge prior to digestion have been pointed out in a number of papers.

12. Composting of municipal wastes and sewage sludge was high-lighted in a symposium of the American Society of Civil Engineers.

13. The demonstration of the possibility of destruction by oxidation of raw sludge at high pressures and temperatures represents a new approach to the sludge disposal problem.

14. The practice of disposal of wastes by spreading or spraying on land for disposal and reclamation is attracting considerable interest.

15. The radioactivity levels of waters (polluted and unpolluted) and means of removing them are reviewed, with some 100 references.

16. Increasing interest in industrial waste problems is manifested by upward of 250 references included. The trend seems to be a continued emphasis on prevention of losses, recovery, spray irrigation, and lagooning for dairy, cannery, and paper mill wastes; biological treatment from the standpoint of better exploitation; specialized applications of the activated sludge process for dairy and paper mill wastes; and continued use of high-rate trickling filters for a number of organic wastes.

17. Interest in biological life in surface waters appears to be high from the standpoints of the effects of various types of pollution, the use of indicator organisms for pollution, fish kills, and environmental conditions (such as the effect of temperature, pH, D.O., specific chemicals, and industrial wastes) for the maintenance of various kinds of fish.

18. Despite the increase in pollution of waters, it is interesting to note that only 11 outbreaks of disease reported in 1953 were traceable to water. Gastroenteritis, amoebic dysentery, and infectious hepatitis were the common diseases attributed to water.

Sewage Works

A METHOD FOR EVALUATING THE VARIABLES IN VACUUM FILTRATION OF SLUDGE *

By A. J. Beck, E. N. Sakellariou, and Max Krup

Sanitary District of Chicago, Ill.

Rotary vacuum filters are used in a number of sewage plants for dewatering digested and activated sludge, and in some cases for dewatering fresh solids sludge. The problem of controlling the filtration of activated sludge is more difficult than other types of sludge because of its higher organic content represented by the biological material present, such as bacteria, protozoa and fungi.

Two laboratory methods, the filter leaf method and the Büchner funnel test, have been in use to investigate and control vacuum filtration. The latter has been the most widely used and numerous reports have been made on this method. As commonly used, the method has one fault. While the filtration time for any type of treatment may be obtained and comparisons made on that basis, no information on comparative moistures in the cake is obtainable because of the loss of vacuum before a normal drying time may be applied.

In this investigation, the Büchner funnel test was modified so that the desired vacuum could be maintained for an extended period of time. By the use of the method not only can the filtration time be determined, but the effect of many of the variables in sludge filtration on moisture in the cake also can be determined. Results obtained using this method to determine the effect of varying the vacuum, the per cent ferric chloride used, the thickness of cake, the drying time, and the age of sludge are given.

History

Experimental work with the activated sludge process for sewage treatment had progressed sufficiently by 1920 that sanitary engineers were designing this type of plant for complete treatment of domestic waste. Trickling filters following sedimentation had been used almost exclusively up to that time.

Although the activated sludge process produced an excellent effluent, no suitable method of disposal of the sludge, an end-product of the process, was at hand. Digestion of activated sludge was tried without much success until later when heated sludge digestion was adopted. Another method, which involved sludge filtration following coagulation with alum or acid, or both, with or without heat, gave some promise. To arrive at the best combination, laboratory tests were indicated. Some of the earliest experiments along this line were carried out by Wilson and Heisig (1).

From the literature on sludge filtration (1–10) it is learned that vacuum filtration of sludge using a Büchner funnel is more than 25 years old. The volume of sludge used has varied from 100 to 450 ml. Results are reported

* Presented at the 27th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Cincinnati, Ohio; Oct. 11–14, 1954.

in terms of time required to collect 75 per cent of the original volume or the time required to the vacuum break. Some investigators reported the moisture content of the cake at the vacuum break and others at intervals up to 20 min. with continually decreasing vacuum.

For more than 10 years, filtration tests were made in the Chicago Sanitary District laboratory using 200 ml. of sludge, adding varying quantities of ferric chloride and noting the pH and the time required to collect 150 ml. of filtrate. The minimum time, of course, indicated the optimum pH and this was used as a guide to ferric chloride dosage in the filter room.

While the method enabled one to determine the filterability of the sludge, it is not suitable for evaluating the variables in sludge filtration under plant operating conditions, which include a reasonably constant vacuum and a drying time of from 3 to 6 min. depending upon the filter speed.

Recently, with extended operations, the need arose for a laboratory method which would show how the moisture in the cake was affected by varying conditions of plant operation such as vacuum, cake thickness, and drying time (filter speed).

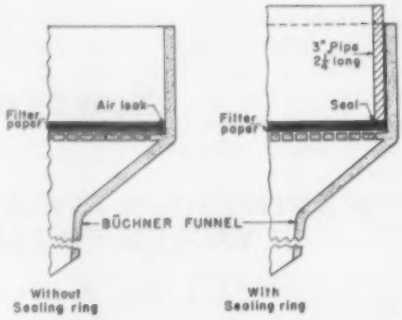

FIGURE 1.—Büchner funnel, with and without sealing ring.

Experimental

In the Büchner funnel test air begins to leak into the system between the paper and the funnel when the excess water has drained from the filter cake.

The first attempt to prevent the air leakage and obtain a constant vacuum was to place a section of 3-in. pipe, 2¼ in. long, on the filter paper in the funnel before pouring the conditioned sludge into the funnel. This did not prove successful because in drying the cake shrank away from the pipe and allowed air to pass.

Next, the Büchner funnel test was made in the conventional way to the point where the excess water was removed. When the air began to leak

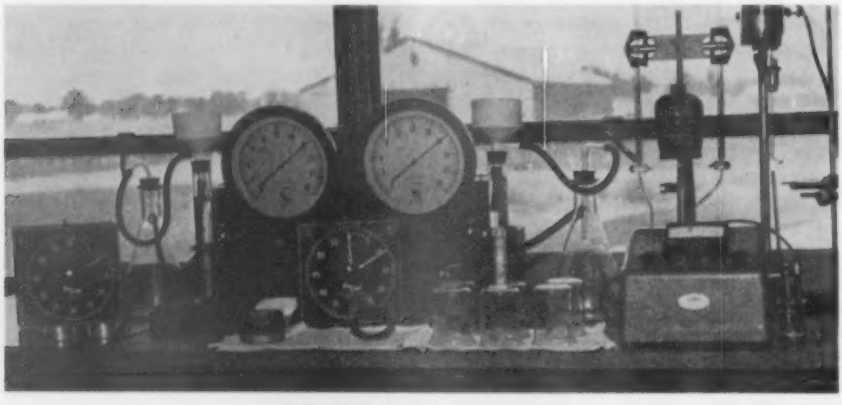

FIGURE 2.—Test equipment.

into the system, reducing the vacuum, the piece of 3-in. pipe was placed in the funnel (Figure 1). This stopped the air leakage and returned the vacuum to the preset level.

A piece of rubber tubing, long enough to dip into the water in the graduated cylinder used as a receiver, was attached to the funnel. In this way, any air leakage could be detected readily and the ring applied.

Test Equipment

The final test equipment used consisted of a vacuum pump with a capacity of 3.5 cu. ft. of free air per minute, a volume tank of 5 cu. ft., two 12-in. vacuum gages, two 9-cm. Büchner funnels, two 250-ml. lipless graduated cylinders, two interval timers, and two 2¼-in. long sections of 3-in. pipe (Figure 2). Piping connections were such that two tests could be made simultaneously, each using the same vacuum, or each at a different vacuum. Needle valves A and B (Figure 3) were provided so that the vacuum to the filter at the left could be throttled by adjusting valve B and not overload the vacuum pump when a small amount of air was bled in through needle valve A to control the vacuum in the funnel at the left at a lower value. The operating vacuum was controlled by a mercoid switch set to start the vacuum pump when the vacuum was reduced ¼ in. of mercury and to stop the pump at 21 in. of mercury. With this equipment two tests could be carried out simultaneously, one at 21 in. and the other at any other vacuum desired.

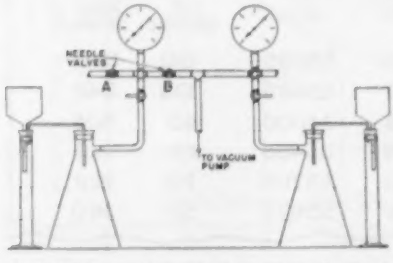

FIGURE 3.—Layout of test equipment.

Modified Büchner Funnel Test Procedure

In practice a sample of sludge was collected, screened through a No. 12 (N.B.S.) sieve and placed in a water bath to maintain the sludge near its original temperature. The solids concentration was determined by treating several 100-ml. portions with a ferric chloride * solution and filtering on filter papers placed in weighed perforated aluminum dishes (10). From the solids concentration, a volume of sludge (200 to 250 or 300 ml.) was selected to produce the desired cake thickness. The sludge was measured in a graduated cylinder and poured into a 400-ml. beaker. Dilute ferric chloride solution of known concentration was measured from a burette into another 400-ml. beaker. The sludge and ferric chloride were mixed by pouring the sludge into the beaker containing the ferric chloride and then from one beaker to another three times; the pH was taken immediately afterward. The interval timer was set at the time the sludge and ferric chloride were mixed. A 5-min. total contact period was used, with occasional stirring during this interval.

After 4 min., a filter paper (Eaton-Dikeman No. 615 †) was placed in the Büchner funnel and a few ml. of water added. Next, the vacuum was applied for a few seconds and the graduated cylinder receiver was emptied. At the end of the 5-min. contact period, the vacuum was applied, the conditioned sludge was poured into the funnel, and the time to collect 150 ml. of filtrate was noted. Filtration was continued and the total time required to remove the excess water recorded. The completion of the removal of ex-

* Laboratory tests indicated ferric chloride addition had little or no effect on the solids determination.

† Approximate equivalent, Whatman No. 1,

WORK SHEET

200 ml. Sample
Activated Sludge
Sludge Temp – 76°F.

Sludge Filtration Test

Aug. 3, 1954
% Solids – 1.80
Vacuum 21"

$FeCl_3$ USED (7.1% $FeCl_3$) (ML)	pH			TIME		FUNNEL NO.	DISH NO.
	Untreated Sludge	Treated Sludge	Filtrate	Filtration (Seconds)	Ring (Minutes)		
3.5	6.8	4.0	5.0	180	8:40	1	47
4.0	6.8	3.4	4.8	103	3:40	1	44
4.5	6.8	3.2	4.7	90	3:05	1	4
5.0	6.8	3.0	4.5	69	2:10	1	43
5.5	6.8	3.0	4.3	70	2:18	1	6
6.0	6.8	2.9	3.9	58	1:40	1	40

FIGURE 4.—Typical laboratory work sheet.

cess water was recognized as that point when air bubbles were first observed in the filtrate receiver. At this time the ring was placed in the funnel, minimizing the air leakage. This was taken as the start of the drying period and continued for 4 min. Air leakage not affecting the vacuum was ignored; if a loss of vacuum resulted, the test was discarded. Loss of vacuum was experienced infrequently and was usually due to overdosing with ferric chloride.

At the end of 4 min., the vacuum was turned off, the funnel was removed from the cylinder and allowed to drain, and the ring and cake were removed. After separation from the

FINAL DATA SHEET

AUG. 3, 1954

Sludge Filtration Test

Activated Sludge
% Solids – 1.80%
Ash – 37.6 %

PERCENT $FeCl_3$ Used	CAKE Moisture %	GRAMS Pick-Up	GRAMS Dry	TIME	
				Filt. (Seconds)	Ring (Minutes)
7.7	81.0	18.7270	3.5695	180	8:40
8.8	79.7	17.6120	3.5685	103	3:40
9.9	79.3	17.4005	3.6000	90	3:05
11.0	78.6	16.5540	3.5468	69	2:10
12.1	78.5	16.6120	3.5705	70	2:18
13.1	78.5	16.6145	3.5625	58	1:40

FIGURE 5.—Typical final data sheet.

filter paper, the weight and the moisture content of the cake were determined. The pH of the filtrate was recorded. Figure 4 shows a typical laboratory work sheet; Figure 5, a final data sheet.

Variables Evaluated

The modified Büchner funnel test as outlined was used to determine the effect of varying the following factors on the moisture content of the filter cake:

1. Vacuum.
2. Per cent ferric chloride.
3. Drying time.
4. Thickness of cake.
5. Elutriation.
6. pH drift.
7. Mixing.
8. Filter media.
9. Age of sludge.
10. HCl addition.
11. Digested Imhoff sludge.

Effect of Varying Vacuum

A 6-l. sample of sludge was collected and a solids determination made. The quantity of sludge was selected to give approximately 3.58 g. of dried solids in the cake. Next, several filtration tests were made to determine a suitable ferric chloride dosage. Once this quantity was determined no change was made. In this case, a 300-ml. volume was dosed with 5 ml. of 7.1 per cent ferric chloride solution to give 11 per cent ferric chloride on the dry basis. The contact time was 5 min. and the drying time was 4 min. Figure 6 shows the moisture in the cake for vacuums from 1 to 21 in. of mercury.

The moisture was reduced from 87.4 to 82.5 per cent by increasing the vacuum from 1 in. to 5 in., to 80.0 per cent at 10 in., and to 78.1 per cent at 21 in. of mercury. Increasing the vacuum produced drier cake, but the curve flattens out markedly above 15 in.

A series of tests was also made using increasing quantities of ferric chloride on the same volume of sludge in two samples run simultaneously, at vacuums of 5 in. and 21 in. of mercury. The results (Figure 7) show that the higher vacuum produces a drier cake at all points. At the higher vacuum increasing ferric chloride dosage pro-

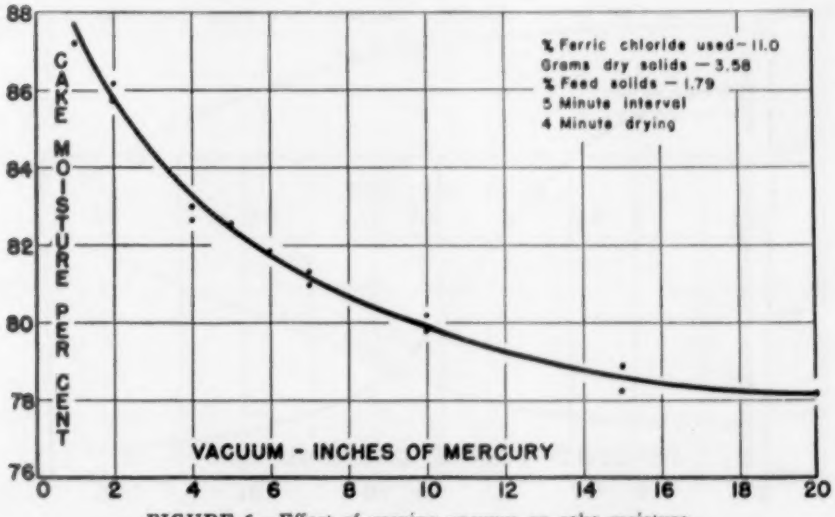

FIGURE 6.—Effect of varying vacuum on cake moisture.

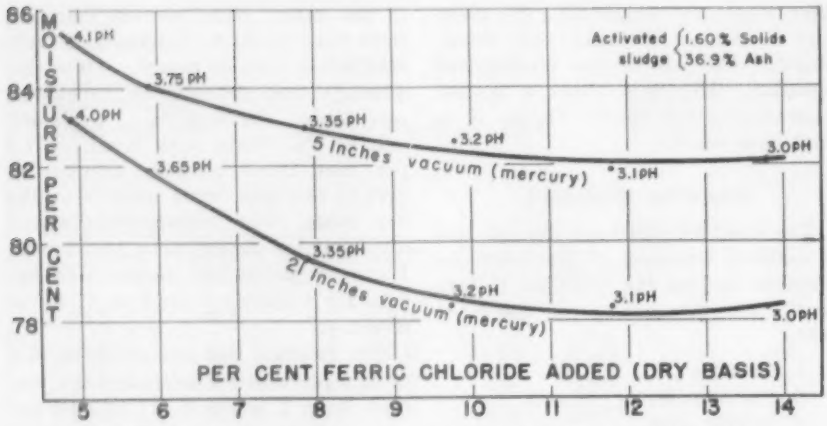

FIGURE 7.—Effect of varying both vacuum and $FeCl_3$ on cake moisture.

duces a greater relative reduction in cake moisture.

Effect of Ferric Chloride Dosage

Portions of sludge (200 ml., 1.60 per cent solids, 39.1 per cent ash) were treated with varying quantities of ferric chloride and filtered at 21 in. of mercury with a 4-min. drying period. The results (Figure 9) indicate sharp reduction in cake moisture when the ferric chloride dosage was increased from 7.3 to 9.8 per cent. Further increase in ferric chloride produced comparatively little reduction in moisture.

Effect of Drying Time

Sludge samples (250 ml., 1.66 per cent solids) were treated with 9.6 per cent ferric chloride, dry basis. The drying time was varied from 1 to 7 min. Other factors, such as 5-min. contact time, 21-in. filtering vacuum, and ferric chloride dosage, were held constant.

The results (Figure 9) show that an increase in drying time from 1 min.

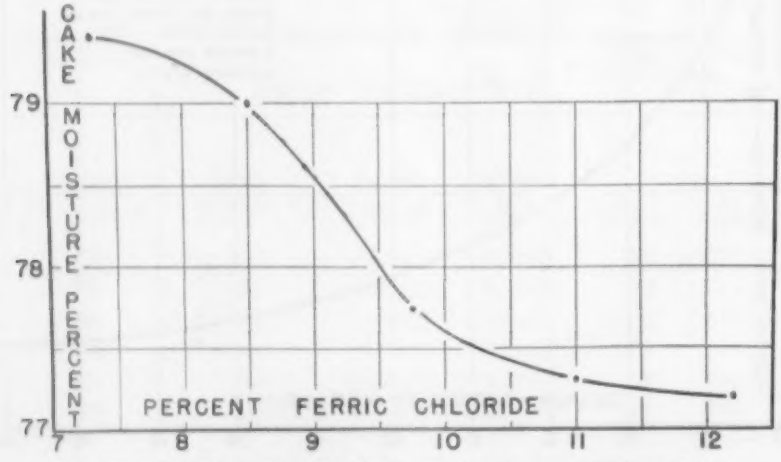

FIGURE 8.—Effect of varying ferric chloride dosage on cake moisture.

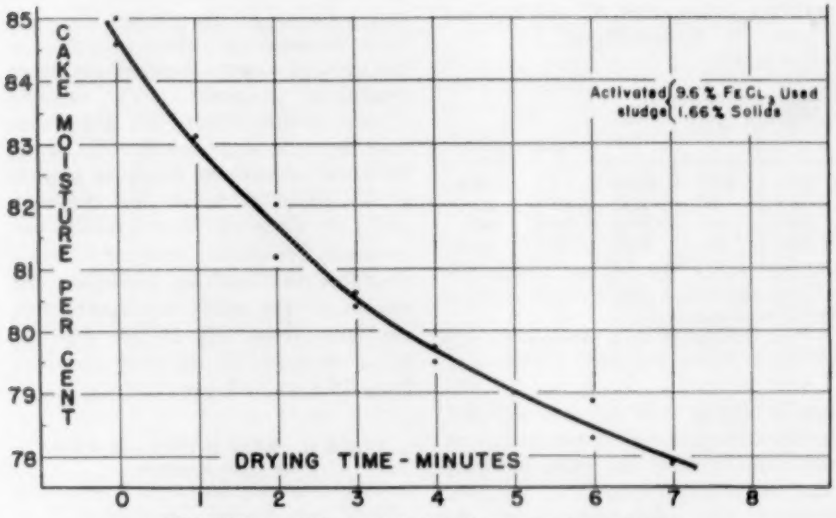

FIGURE 9.—Effect of drying time on cake moisture.

to 7 min. decreased the moisture in the cake from 83.1 to 77.8 per cent.

The literature on sludge filtration tests shows some data on moisture in the cake at the vacuum break time. To learn how such a test correlated with the one just described, as well as how it compared with the ordinary filtration test and the time to the vacuum break, duplicate samples were treated with varying quantities of ferric chloride. One sample was allowed to dry for 4 min.; the other was removed when the air bubbles were first observed in the filtrate receiver. Moisture was determined.

Table I and Figure 10 show that as the ferric chloride was increased, the

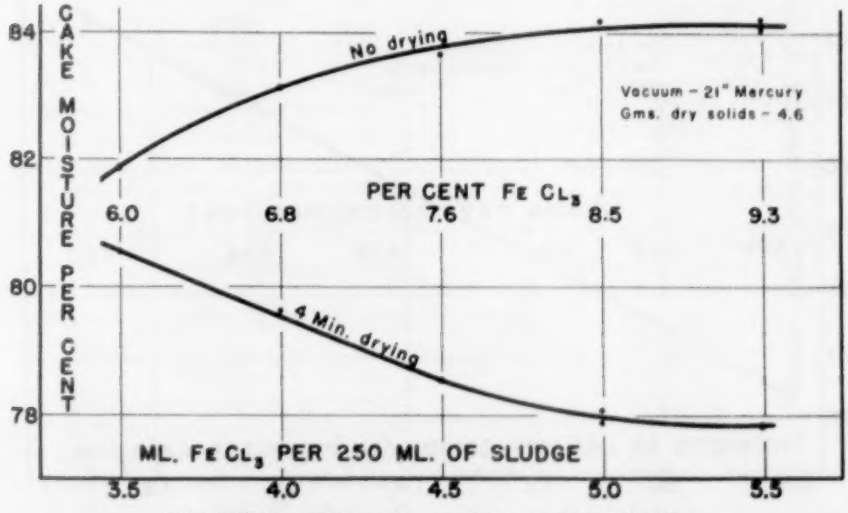

FIGURE 10.—Cake moisture with and without drying.

TABLE I.—Sludge Cake Moisture With and Without Drying

$FeCl_3$ Used (%)	Filtr. Time[1] (sec.)	Vacuum Break Time[2] (min.)	Cake Moisture (%)	
			With Drying	Without Drying
6.0	115	15:30	81.1	82.4
6.8	74	4:55	80.2	83.7
7.6	47	3:15	79.1	84.2
8.5	38	2:25	78.3	85.0

[1] Time required to collect 150 ml. of filtrate from 250-ml. sample.

[2] Time required to drain excess water with resulting air leakage and loss of vacuum.

time to collect 150 ml. was reduced, the filtration time to the vacuum break was reduced, and the cake moisture after 4 min. drying was reduced. However, the cake moisture at the vacuum break increased with each increase in ferric chloride. It was concluded that moisture content of the cake at the vacuum break is not a suitable parameter.

Effect of Thickness of Cake

A quantity of sludge from the supply to the filter room was used in this test. Cakes of increasing thickness were obtained by filtering increasing amounts of sample, holding all other conditions constant. The results (Table II and Figure 11) show that cake moisture increases directly as the thickness of cake in terms of pounds of dry solids per square foot per hour ($11\frac{1}{2}$-ft. diameter filter making one complete revolution every 6.5 min.) Doubling the load by increasing the weight of dry solids per square foot per hour from 0.81 to 1.65 resulted in an increase in the cake moisture from 76.4 to 81.2 per cent.

TABLE II.—Effect of Thickness of Cake on Cake Moisture

Sample Size[1] (ml.)	Cake Moisture (%)	Dry Solids		
		(g.)	(lb./sq. ft. filter area)	(lb./sq. ft./hr.)
200	76.4	2.7340	.088	0.81
250	77.5	3.4240	.110	1.01
300	78.7	4.1510	.133	1.22
350	80.0	4.8690	.157	1.45
400	81.2	5.5390	.179	1.65
450	82.3	6.1650	.200	1.84

[1] 11.5 per cent $FeCl_3$ used; 31.8 per cent ash.

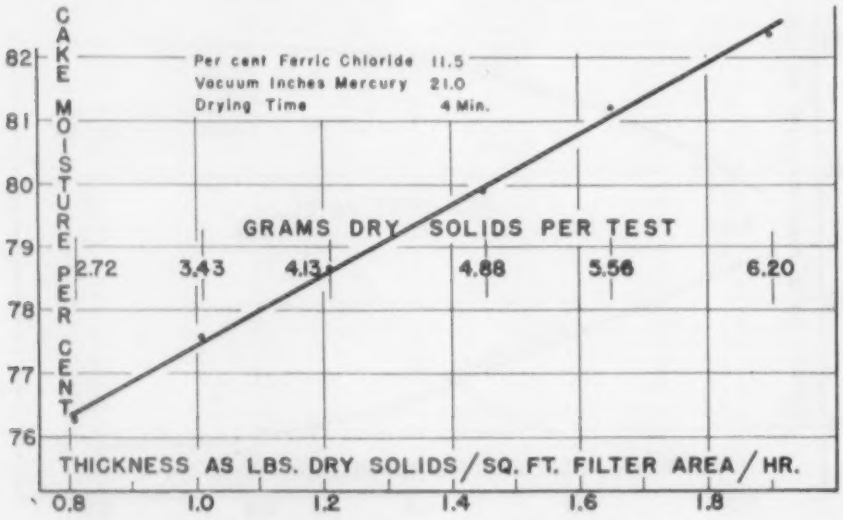

FIGURE 11.—Effect of cake thickness on cake moisture.

TABLE III.—Effect of Elutriation[1] of Activated Sludge on Cake Moisture

Sample	$FeCl_3$ (%)	Cake Moisture (%)	Dry Solids (g.)	Filtration Time (sec.)
Original	8.2	81.2	3.7650	19
Original	8.2	81.4	3.7910	20
Original	8.2	81.1	3.7695	20
Original	8.2	81.1	3.8145	20
Elutriated	8.0	79.4	3.8710	14
Elutriated	8.0	79.8	3.8897	13
Elutriated	8.0	79.7	3.8910	15
Elutriated	8.0	80.3	3.9090	15

[1] Elutriation consisted of one volume activated sludge to two volumes of tap water, settled 3 hr. to original volume.

Elutriation of Activated Sludge

One volume of sludge was mixed with two volumes of tap water and allowed to settle to the original volume. The excess water was removed by decantation. Filtration tests were made on the original sludge and on the elutriated sludge. The results (Table III) indicate that elutriation caused a 1.4 per cent reduction in cake moisture. The filtration time (seconds to collect 150 ml. of filtrate) also was reduced.

pH Drift

It has been reported that filtration promptly after dosing gives best results and any undue delay permitting the pH to drift upward is detrimental to filtration. Table IV shows that pH drift had no effect on cake moisture up to 30 min. However, the filtration time increased and in plant operation increased time between dosing and filtration with corresponding lower filtration rate results in lower filter capacity.

Mixing

It has been believed in the profession that any treatment which broke the floc was detrimental and should be avoided. A series of tests was made to determine the effect of mixing on cake moisture. Sludge taken from the supply to the filter room with a solids content of 1.68 per cent was treated with 8.3 per cent ferric chloride. Filtration tests were made with mixing times from 0 to 30 min. The results (Table V) show no change in cake moisture up to 30 min. Mechanical stirrers were used for mixing. The filtration time (time to collect 150 ml.) and the ring time (time to remove excess moisture) are practically doubled with 30-min. mixing. This was expected, since contact without mixing increased filtration time.

TABLE IV.—Effect of pH Drift on Cake Moisture

Interval (min.)	pH		Filtr. Time (sec.)	Cake Moisture (%)
	Orig.[1]	Final[2]		
1	3.6	4.1	93	82.8
1	3.6	4.15	97	82.3
5	3.6	4.35	77	82.7
5	3.6	4.35	81	82.5
5	3.55	4.5	75	82.3
5	3.55	4.5	75	82.3
10	3.55	4.7	85	82.2
10	3.55	4.75	95	82.8
15	3.6	4.8	100	82.4
15	3.6	4.75	110	82.7
30	3.6	4.9	135	82.8
30	3.7	4.95	118	82.2

[1] Taken immediately after mixing sludge with 8.5 per cent $FeCl_3$.

[2] Taken after waiting interval and immediately preceding filtration.

Filter Media

Dacron filter cloth was compared with the filter paper used in the lab-

TABLE V.—Effect of Mixing on Cake Moisture and Filtration Time

Mixing Interval (min.)	Cake Moisture (%)	Filtr. Time[1] (sec.)
0	80.0	71
5	79.7	83
10	79.5	98
15	79.7	108
30	79.9	139

[1] Time to collect 150 ml. of filtrate from 250-ml. sludge sample.

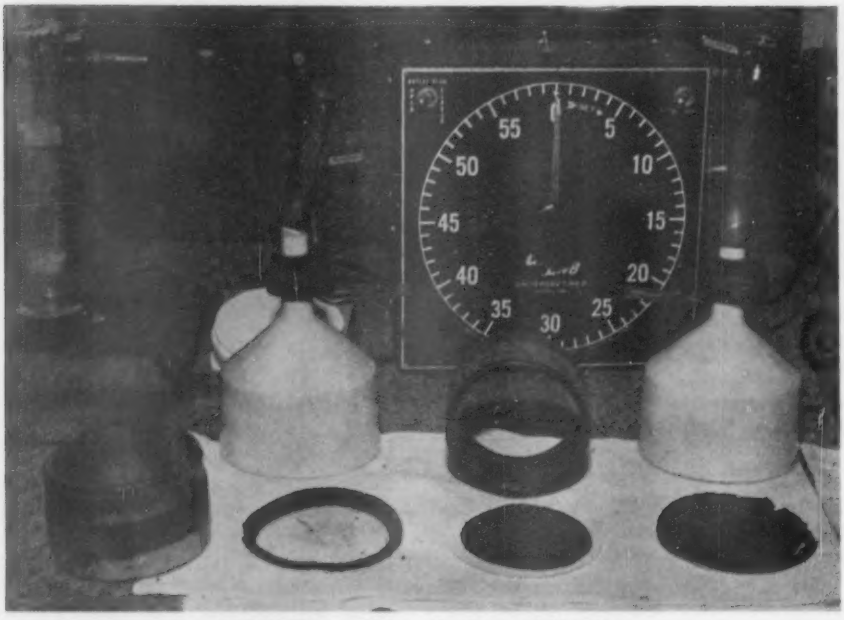

FIGURE 12.—Filter cake from within ring.

oratory. The cloth was fastened to the Büchner funnel at the periphery with a bituminous material. To obtain about equal and significant portions of cake from each funnel, only the cake from the area inside the ring (Figure 12) was used in the moisture determinations. No difference was found in the cake moisture (Table 6) although the cloth gave a slightly lower and less uniform filtration time.

TABLE VI.—Comparison[1] of Cloth[2] and Paper Filters

Cake Moisture (%)	Filtration Time (sec.)
(*a*) Dacron Cloth	
76.2	28
76.3	27
76.1	26
76.3	25
76.0	24
75.7	22
75.6	23
(*b*) Paper	
76.1	26
75.8	26
75.6	26
74.4	26
76.4	26

[1] Test conditions: Activated sludge with 1.41 per cent solids containing 43.9 per cent ash; 5-min. contact time; 4-min. drying time; 21-in. vacuum; and 6.3 per cent $FeCl_3$ dosage.

TABLE VII.—Effect of Sludge Age on Cake Moisture Content; Constant $FeCl_3$ Dosage

Sludge Age (hr.)	$FeCl_3$ Dosage (%)	Cake Moisture (%)	Time	
			Filtr. (sec.)	Ring (min.)
6	8.25	78.7	34	1:40
10	8.25	79.7	45	2:33
29	8.25	81.5	120	8:40
53	8.25	82.0	140	11:40

Age of Sludge

A sludge sample was obtained by settling the aeration mixture for 6 hr. Filtration tests were made 6, 10, 29 and 53 hr. after the original sampling.

TABLE VIII.—Effect of Sludge Age on $FeCl_3$ Demand to Maintain Same Moisture Content

Sludge Age (hr.)	$FeCl_3$ Required (%)	Cake Moisture (%)	Time	
			Filtr. (sec.)	Ring (min.)
6	8.25	78.7	34	1:40
10	9.20	78.7	34	1:37
29	11.90	78.6	35	1:55

The sample was stored at its original temperature until used.

Table VII shows that when 8.25 per cent ferric chloride was used the moisture in the cake increased from 78.7 per cent at 6 hr. to 82.0 per cent at 53 hr. and filtration time increased from 34 to 140 sec.

Table VIII shows that at 29 hr. 11.9 per cent ferric chloride was required to approximate the cake moisture obtained at 6 hr. with 8.25 per cent ferric chloride.

Effect of Prior Acid Treatment

Tests were made to determine if treating sludge with HCl followed by ferric chloride addition would produce a saving in ferric chloride or produce a drier cake. Samples of sludge (200 ml., 2.00 per cent) were treated with hydrochloric acid, followed by ferric chloride. The quantity of HCl added was maintained at 1.43 per cent, while the ferric chloride concentration was varied from 7.8 to 10.7 per cent. Another sample with the same ferric chloride content and no acid was filtered at the same time. Table IX shows that, in general, the addition of HCl reduced the pH of the sludge. No improvement was noted in the cake moisture over the samples where only ferric chloride was used. An increase in filtration time and ring time was noted.

Digested Sludge

Well-digested Imhoff tank sludge was treated with varied dosages of ferric chloride and a constant 10.8 per cent of hydrated lime. After 2 min. mixing with the ferric chloride, the lime was added and mixing continued for 3 min. before filtering.

The results (Table X) show that increasing the ferric chloride from 0.28 to 1.68 per cent reduced the cake moisture from 67.8 to 64.8 per cent. Increasing the ferric chloride to 2.24 per cent resulted in no further decrease in cake moisture.

Table XI shows the results of varying the lime dosage using a constant quantity of ferric chloride. Using 1.8 per cent ferric chloride and no lime, the cake moisture was 69.8 per cent. With the addition of 3.8 per cent hydrated lime, 68.1 per cent; with 7.6 per cent lime, 67.1 per cent; and with 11.4 per cent lime, the cake moisture was 63.3 per cent. Increasing the quantity of lime added from 3.8 to

TABLE IX.—Effect on Cake Moisture of HCl Treatment of Sludge Before $FeCl_3$ Addition

Cake Moisture (%)	$FeCl_3$ Dosage (%)	HCl Dosage (%)	pH				Time	
			Untreated	HCl	$FeCl_3$	Filtrate	Filtr. (sec.)	Ring (min.)
80.9	7.8	—	6.6	—	3.5	4.5	118	5:10
80.8	7.8	1.43	6.6	5.0	2.6	3.75	145	6:05
80.4	8.8	—	6.6	—	3.1	4.4	90	3:15
80.5	8.8	1.43	6.6	5.0	2.55	3.5	132	4:52
79.7	9.75	—	6.6	—	2.85	3.9	78	2:45
80.1	9.75	1.43	6.6	5.0	2.3	3.15	129	4:40
79.6	10.7	—	6.6	—	2.7	3.85	85	2:55
79.8	10.7	1.43	6.6	5.0	2.25	3.15	134	4:35

TABLE X.—Effect of Varying $FeCl_3$ Dosage on Treatment of Imhoff Sludge

$FeCl_3$ Used (%)	Lime Used (%)	Cake Moisture (%)	Ring Time (min.)	pH of Treated Sludge
0.28	10.8	67.8	13	12.3
0.56	10.8	67.3	9:30	12.1
1.12	10.8	65.7	5:30	12.1
1.68	10.8	64.8	3	12.1
2.24	10.8	64.9	2:30	12.1

11.4 per cent reduced the moisture content in the cake with each increase in lime.

Summary

The Büchner funnel test has been modified by sealing the periphery with a ring to prevent air leakage so that a constant vacuum may be maintained for an extended period of time.

The results of the filtration experiments using this modified method indicate that on vacuum filtration:

1. Moisture in the cake was reduced as the operating vacuum was increased.
2. Increasing ferric chloride dosages, in the 5 to 10 per cent range, resulted in lower cake moistures.
3. Moisture in the cake was reduced as the drying time was increased.
4. Cake moisture increased directly as the thickness of cake was increased.
5. Elutriating sludge with tap water improved the filterability slightly and resulted in a little lower cake moisture than the unelutriated sludge dosed with an equal amount of ferric chloride.
6. Contact time (pH drift), or delayed filtration after dosing, up to 30 min. had no effect on cake moisture; the filtration time, however, increased with increased contact time.
7. Mixing of sludge after conditioning had little effect on the moisture in the cake; the filtration time was increased with increased mixing time. This was to be expected, as increased contact time alone caused an increase in filtration time.
8. Dacron cloth and filter paper gave the same cake moistures under the same filtering conditions.
9. As the storage time of activated sludge before filtration was increased, the moisture in the cake increased when the same concentration of ferric chloride was used; increased quantities of ferric chloride were required to obtain the same moisture in the cake.
10. Adjusting the pH of activated sludge with hydrochloric acid prior to ferric chloride treatment showed no saving in ferric chloride and no improvement in filtration time.
11. Tests on digested Imhoff sludge showed that the conditioning effect of both lime and ferric chloride based on cake moisture could be determined by this testing procedure.

TABLE XI.—Effect of Varying Lime Dosage on Treatment of Imhoff Sludge

$FeCl_3$ Used (%)	Lime Used (%)	Cake Moisture (%)	Ring Time (min.)	pH of Treated Sludge
1.8	—	69.8	17	6.2
1.8	3.8	68.1	13	7.9
1.8	7.6	67.1	4:15	11.0
1.8	11.4	63.3	3	11.8

Acknowledgments

The Sanitary District of Chicago, Southwest Sewage Treatment Works, where the experiments were conducted, is under the direction of W. A. Dundas, General Superintendent; Phillip Furlong, Engineer of Maintenance and Operation; F. W. Mohlman, Director of Laboratories; and A. H. Goodman, Engineer of Plant Operation. The authors are indebted to C. P. McLaughlin, Engineer of Mechanical Design, and the personnel of his department for the work on the figures and tables, Ray Hill for the photographic work, and J. M. Mercer and G. G. Poindexter for aid in organizing the material. John Roman assisted in the experimental work.

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DISCUSSION

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To those engaged in operating plants using mechanical dewatering equipment, this paper is interesting and valuable. The authors have refined the technique of the Büchner funnel test in such a manner that each variable can be isolated and performance evaluated.

It is realized that the Büchner funnel test as generally performed has limitations; but if these are recognized it is a valuable tool for the evaluation of trends in filtration purposes. Fortunately, the time to vacuum break, as shown in Table I, correlates both the filtration time and the cake moisture obtained after dewatering on the large filters—therefore, the time to vacuum break can be used as a control measure in coagulant dosage rates.

However, a satisfactory laboratory filtration procedure should be applicable not only to the control of operations, but also in the research and development of process improvements, new processes and new materials. The past few years have seen the emergence of many synthetic fibers to compete with wool or cotton cloth. In certain cases, competitive situations have arisen in the use of chemicals. Frequently direct or indirect pressure is brought upon the plant manager to use a certain type of chemical or cloth. The Büchner funnel, the laboratory test filter leaf, as well as pilot-plant rotary vacuum filters can be used both for the control and for the evaluation of new materials, coagulants, and processes. Garber (11) has pointed out the advantages of thermophilic digestion at Los Angeles, principally as to filter rates obtained with the sludge so produced. This important step was detected by use of the filter leaf test, and plant-scale tests thereafter confirmed the filter leaf findings. As a result, thermophilic digestion has been adopted for about 50 per cent of the sludge digested at Los Angeles.

Inasmuch as certain limitations of the Büchner funnel test had been realized, efforts at Los Angeles were bent toward development of the filter leaf

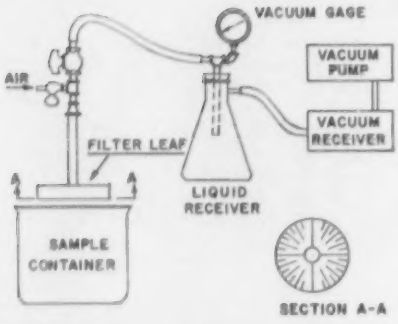

FIGURE 13.—Typical filter leaf test setup.

test. A typical filter leaf setup (Figure 13) comprises a laboratory-type vacuum pump, a vacuum receiver, a liquid receiver, and the filter leaf itself. The type of filter leaf employed in the tests is such that 0.1 sq. ft. of area can be covered by the cloth under test or the process under test. By holding the vacuum constant on the filter leaf during the pickup and drying cycle, the variables can be evaluated just as the authors have done with the Büchner funnel test.

The standard method of running the filter leaf test is as follows: A 2-gal. sample of sludge is conditioned with coagulant in a container. After mixing, the sludge is allowed to stand for the calculated time of travel from the dosing point in the filter room to the filter drum. A vacuum equal to that on the operating filters is applied and the filter leaf is then immersed in the sample and gently and slowly moved through the conditioned sludge. At the end of 1½ min. the filter leaf is gradually brought around into a vertical position and the cake is vacuum dried just as on the filter drum. At the same time it is under a constant vacuum such as obtains on the filter itself. In the Hyperion plant this drying time is 3 min. At the conclu-

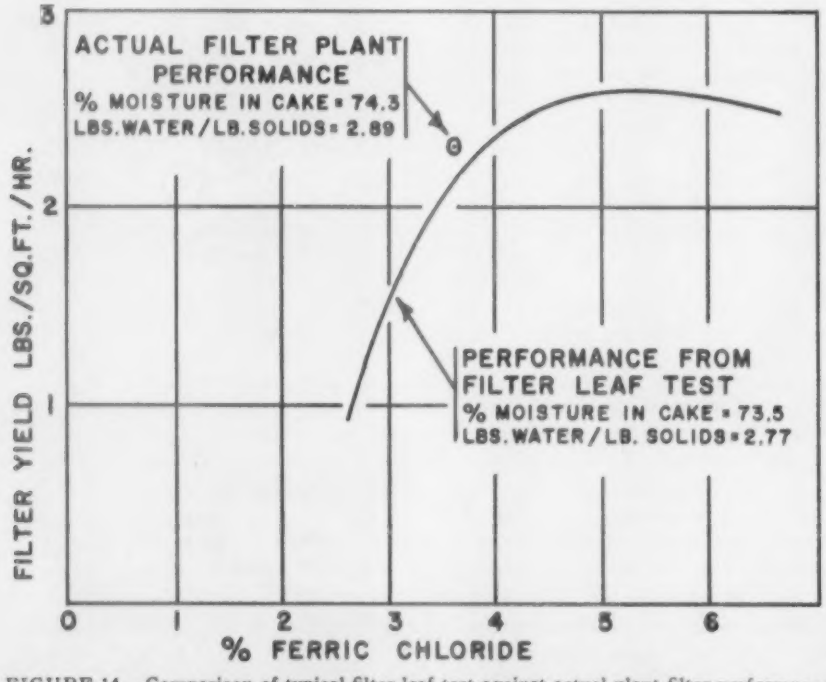

FIGURE 14.—Comparison of typical filter leaf test against actual plant filter performance.

sion of the drying cycle the leaf is subjected to a 2 p.s.i. air blow-off, just as on the main filters. This takes place for one-half minute. Therefore, the total time of filter test, or one rotation of the drum, is 5 min. This has been adopted as the standard test procedure at Hyperion because it closely approximates filter room performance and, therefore, the laboratory can evaluate effectively such items as new cloths and different coagulants. The cake is then transferred to a tared dish, weighed wet, dried at 105° C., and weighed dry. Taggart (12) gives an excellent description of the filter leaf equipment and test procedures.

The filter leaf test has been used for some time by certain manufacturers of vacuum filter equipment to determine the loading rates of products prior to recommending size and type of installation. In general, filter yields in actual practice should be at least 80 per cent of the yields obtained by the filter leaf test. From time to time at Hyperion the laboratory makes filter leaf tests of sludge actually being delivered to the filter room floor, and the performance of the plant itself is checked against the filter leaf results. A typical test is shown in Figure 14.

It is noted that the authors have used "per cent moisture in filter cake" rather than the usual pounds per square foot per hour of yield as the ordinate in many of the charts presented. This is not surprising, because quite often the process of filtration is followed by a drying process involving the purchase of fuel. The percentage of moisture in the feed to the drying process is important not only from the fuel consumption view-

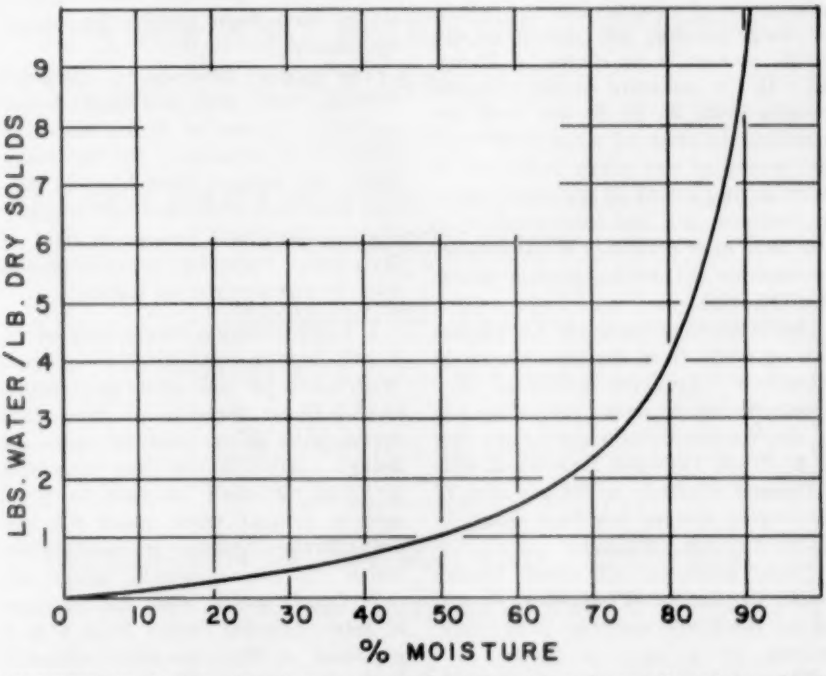

FIGURE 15.—Relationships between percentage of moisture in sample and pounds of water per pound of dry solids in sample.

TABLE XII

Dosage $FeCl_3$	Filter Cake Moist. (%)	Water Evaporated* (lbs./lb. dry solids)	Cost/Ton Final Product*		
			$FeCl_3$	Fuel	Total
7.3	79.35	3.76	6.09	3.90	9.99
8.5	79.00	3.68	7.09	3.82	10.91
9.8	77.50	3.35	8.17	3.48	11.65
11.0	77.25	3.30	9.18	3.42	12.60
12.2	77.25	3.30	10.18	3.42	13.60

* To bring final product to 8 per cent moisture.

point, but also because in certain drying processes a higher percentage of moisture in the feed means a greatly increased recycling process load in the drier. The pounds of water to be evaporated per pound of dry solids processed is the significant factor in drying processes following vacuum filtration, and the percentage moisture ordinate does not quite show the true significance. The relationship between percentage of moisture and the pounds of water present per pound of dry solids present is as shown in Figure 15. If the moisture in the cake increases from 75 to 80 per cent, the resultant increase of pounds of water per pound of dry solids is from 3 to 4, or an increase of 33 per cent. Thus, an increase of 5 per cent moisture in the filter cake results in a 33 per cent increase on the drying process following filtration.

An interesting economic comparison can be made from the data shown in Figure 8. Applying prices as they obtain in Los Angeles ($90.64 per ton of ferric chloride and gas or oil fuel at $0.30 per 1,000,000 B.t.u.) and with a thermal efficiency of 60 per cent in the drying system, the data shown in Table XII are obtained.

Thus, assuming all other factors equal, the increased coagulant dosage to get the lower moisture is not warranted.

The authors' experience on elutriating activated sludge is quite interésting. One might consider activated sludge concentrated to 1½ per cent solids to be, if not a true colloid, at least a suspension. It is well known that if a suspension has its solute changed, very often coagulation will occur. This may be noticed, for instance, when determining grease in sludges in the laboratory. It may be that the new solute (tap water) is just enough different from the normal activated sludge solute (that is, water having a soluble B.O.D. of perhaps 10 p.p.m. and some near-soluble organic compounds present) to initiate partial coagulation and, therefore, require less ferric chloride to coagulate. Because the solute concentration of materials having a chemical demand is very low, the results are, of course, nowhere near as spectacular as they are with elutriation on a digested sludge. The results that can be obtained with elutriated and digested sludge have been previously covered by Genter.

The authors have mainly discussed filtering tests with activated sludge, no doubt because of the process' importance at Chicago. On the other hand, the writer's tests have in general been with elutriated and digested sludge, since said process is used at Hyperion. Hyperion filtration results may be summarized as follows:

1. Little filtration occurs until about 3 per cent ferric chloride is used. With 3 to 5 per cent of ferric chloride, almost linear increase of filter rate occurs with an increase in coagulant dosage. After 5 per cent coagulant is added, a small increase in filter rate is evident until about 6.5 per cent ferric chloride is used, after which the rate gradually drops off.

2. Concurrently with the increase in ferric chloride dosage from 3 to 5 per cent a drier cake is delivered from the vacuum filters. The mois-

ture drops from an average of about 75 per cent at 3 per cent ferric chloride to 73 per cent at 5 per cent ferric chloride.

Rather than to discuss results obtained at Hyperion, it is preferred merely to state that in general they support the authors' findings.

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INCREASED INCOME FROM INVENTIONS*

By A. J. Fischer

Assistant Manager, Development Department, The Dorr Company, Stamford, Conn.

Contrary to popular opinion most of the major process inventions being commercialized or commercially developed in the sanitary field today have been originated by consulting and municipal engineers and plant operators and not by employees of equipment manufacturers. Typical examples are the thickening processes of Goudey, Torpey and Laboon, the digestion processes of Buswell and Imhoff, the trickling filter processes of Jenks and Ward, the activated sludge processes of Pirnie, Kraus and Gould, and the sludge filtration processes of Genter and Kennedy. However, as one might expect, manufacturers' employees are responsible for most of the advances in mechanical equipment designs, although a number of important machines used in the field have been originated by men not employed by equipment companies (for example, the flocculation units of Smith and Langelier; the digesters of Keefer, Pruss and Downes; the clarifiers of Trebler and Skinner; the aerators of Powers and Currie; the grit chamber of Camp; the comminutor of Nordell; and the filter of Komline. Curiously enough, relatively few of the processes and machines in successful use today have had their genesis in non-commercial research laboratories or are the product of the minds of men engaged in the educational field. Exceptions to this generalization are the inventions in the field of trickling filters by Levine and Halverson, of flocculation by Langelier, and of digestion by Buswell.

Considering the opportunities afforded to men in the design, operation and research fields to develop novel and patentable ideas, it is surprising that more inventions are not made by them considering the possible monetary rewards. The inescapable conclusion to be drawn is that all too many individuals do not know when they have made an invention, or having recognized that they have made one, do not know how to adequately protect it and commercialize it. Broadly speaking, in the United States an invention is considered patentable if it involves a process, a system or an apparatus that is new and which produces an unexpected result. Further, it must not be in public use or disclosed in a printed publication more than one year prior to the filing of a patent application covering the idea. The mere possession of an idea in the mind of an individual does not constitute invention. Under the law it is desirable that the idea be diligently reduced to practice, or a patent application be diligently filed, which in the eyes of the law constitutes a reduction to practice.

As a first step, when one believes he has conceived a novel idea a "Record of Invention" should be made. This should be a clear detailed description of the idea and with appropriate sketches, flowsheets, etc. Accompanying this record should be a statement as to when, where, how and why the idea was conceived and to whom it was disclosed. This document should be signed and dated by

* Presented at 27th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Cincinnati, Ohio; October 11–14, 1954.

the inventor on each page. Likewise, each page should be signed and dated by two witnesses who have read and understood the description. Such records, coupled with due diligence in reducing the invention to practice, are of considerable value in establishing prior and original inventorship when two parties file patent applications covering the same invention. In such a case an "Interference" may be declared by the Patent Office and each party may be required to submit evidence supporting his date of conception, date of reduction to practice, and record of diligence from date of conception to date of reduction to practice. In such cases the party wins the interference who clearly proves he has been diligent and is the first and original inventor. In about 25 per cent of such interferences the first inventor actually has the later filing date.

The next step to be taken by an inventor depends upon whether he wishes to obtain a patent on his idea himself or whether he wishes to immediately interest an equipment manufacturer in it. Unless the inventor desires to commercialize his idea personally, the latter is by far the more desirable procedure, as in most cases the equipment manufacturer will undertake to have carried out through competent attorneys all the necessary patent work involved, including the patentability search, preparation of the specification, prosecution of the case through the Patent Office, and payment of fees. Added advantages in this procedure are that commercial organizations retain patent attorneys experienced in the field so that there are better chances of obtaining good patent protection on the particular process or apparatus involved; also development and/or commercialization of the invention may be put in hand at once, long before the patent actually issues.

Where an inventor desires to obtain patent protection himself, the best procedure is for him to consult a patent attorney who can carry out all phases of the necessary work for him. The first step, a patentability search, may be simple or complex, depending on the nature of the invention. It involves a review of issued patents to determine whether there are any anticipating references. A simple search may cost as little as $25, whereas a more complete one may cost $100 or more depending on the time required to conduct it. In addition, it is desirable to make a literature search to determine whether the idea has been disclosed in any of the technical publications. The next phase, involving the preparation of a patent application and prosecution through the Patent Office, etc., may easily cost anywhere from about $400 to $4,000, depending on the attorneys selected, complications encountered in the prosecution of the case, etc. This cost can be kept to a minimum if the inventor supplies his attorney with complete information regarding his invention with all possible modifications at the time the patent application is being prepared. It has taken an average of slightly more than three years for a patent to issue in the United States in the sanitary field, after the date of application. A study of 100 fairly well-known sewage treatment patents has shown a spread of from seven months to seven years in time of issue. The life of the patent is 17 years from the date of issuance. It is generally considered, however, that the commercial life of a patent in the sanitary field is only about eight to ten years. That is, if an inventor waits until a patent issues before he attempts to commercialize it, about five to seven years is spent in developing and demonstrating the invention so that it may find wide acceptance. Therefore, the royalty earning capacity of an invention is materially lengthened if it is commercialized immediately.

United States Patents may be reissued to broaden their claims within two years of the date of issue, provided the broader claims are supported by disclosures in the application. After the two-year period, patents may be reissued only for the purpose of correcting errors in substance and narrowing of claims. In neither case does the reissuance of a patent extend the life of the original patent.

This brings us back to the all-important consideration regarding the commercialization of an invention by the inventor himself or through an equipment manufacturer. If the invention has a fairly wide field of application, can be readily demonstrated to have economic advantages, and if the inventor has an independent source of income or financial backing at his disposal, he might be able to market the invention advantageously himself. Such cases of self-exploitation have been extremely rare in the field of sewage treatment. At the moment, only four can be recalled—Genter with his elutriation process, Komline with his vacuum filter, Mallory with his activated sludge system, and Hays with his contact aerator.

The question is often asked: "How can I find out if my idea is of commercial interest?" This may be readily done by contacting one or more established manufacturers in the field. Such companies are always on the alert for new ideas and will give their opinions freely regarding their further interest in the idea at hand. A turn-down by one company does not necessarily mean that the particular idea will not find a market in the industry. Equipment manufacturers who examine new ideas are not infallible in their evaluations and at times may exhibit unwarranted prejudices. Therefore, it is unwise for an inventor to become discouraged until he gets at least three refusals or is presented with positive proof that his idea is not novel. Further, he should be selective in the company he approaches. Normally, it is not wise to submit an idea for a pump to a manufacturer of meters, or a clarifier mechanism to a valve manufacturer. Also, it is a fallacy to believe that a manufacturer of an established aerator is not interested in a new aerator, or a competing trickling filter. There are cases, however, where manufacturers are desirous of expanding their existing lines and may be interested in items that they are not now producing.

Other questions often proposed are: "Am I safe in disclosing my idea to a manufacturer before it is protected by patents?" and "Will my idea be treated as being confidential?" To the first question the answer is "Yes." The inventor's "Record of Invention," as discussed earlier, should be adequate for establishing his date of conception. To the second question, a qualified "no" must be given. There are many reasons for this stand, among them being the following:

1. The company to which the idea was referred may have already had the same idea originate with its own personnel or with others.
2. To properly evaluate the idea it may be necessary to discuss it with outsiders.
3. The idea may be in the public domain.

Therefore, by accepting a submitted idea on a confidential basis a company may be unfairly restricting itself in regard to information already in its possession or of an unpatentable nature. It also limits itself in properly evaluating the idea. Some large companies, such as General Electric, refuse to accept any ideas submitted on a confidential basis. It is reasonable to expect, however, that any company to which an idea has been submitted will use its best efforts to protect the interests of the inventor.

After an inventor and an equipment company decide that it is to their mutual interests to work together on the marketing of an invention, the basis of an agreement must be worked out. Uppermost in most inventors' minds before this is done is the question: "How much do I get for it?" This depends on a number of factors, chief among them being:

1. The nature and importance of the invention.
2. Market possibilities.
3. The amount of development work required before the invention is ready for commercialization.

Rights to minor machine improvements, gadgets, sampling devices, etc., are oftentimes sold outright for a nominal sum. Most process and major apparatus rights are licensed on a fixed royalty basis for each unit or plant sold. An inventor can usually realize more from royalty income than from an outright sale of a major invention. He can be sure that if someone offers him say $10,000 for his invention, there is a possibility that he may gross as much as $100,000 from royalties. Also, if annual minimum royalties are called for, the royalty payments will be considerably less than where no such cash commitments are made. As a rule, companies avoid making any cash payments or minimum guarantees, even where an invention is patented and tested or even used commercially. The reason for this is that the additional amount of development work usually required to commercially demonstrate a process or apparatus before it gains wide acceptance is so great that such payments or guarantees are not justified.

A few cases in point illustrate this. In one case, development costs of a process in commercial use at the time of its acquisition amounted to about $17,000 before it could be successfully sold. In another, not yet "out of the woods," costs so far have amounted to $30,000. On the average, it is a fair assumption to estimate technical development costs of a machine in the sewage treatment field at between $15,000 to $25,000 and of a process between $35,000 to $50,000, with some running far in excess of these figures. In fact, these figures do not include any patent or design costs, which may well double the over-all development costs. In addition to these costs on productive inventions, equipment companies carry out extensive development work on many ideas that find little or no commercial acceptance, despite their technical soundness and apparent attractiveness at the time they are taken over. These unproductive inventions often cost as much as those that become commercially accepted.

Royalty payments may be based on any one of a number of factors such as:

1. A percentage of the license fee charged the customer by the manufacturer for use of the invention.
2. A percentage of the selling price of the equipment involved.
3. A percentage of the estimated gross profit on the equipment involved.
4. An amount based on design flow to be treated.
5. An amount based on equivalent design population to be served.
6. An amount based on area or volumetric contents of the units covered by the invention.
7. A flat sum per unit sold.

A combination of 1 and 2, or of 1 and 6 have been most frequently used in the sanitary field. Each method has its advantages, depending on the nature of the invention. Regardless of how royalties are computed, however, one can be sure that almost invariably they relate back to a percentage of the selling price of the equipment covered by the claims of the patent and sold by the manufacturer. This percentage figure will de-

pend on the status of the invention; that is, whether any patent work has been done on it, whether it has been tested or commercially demonstrated, the value of the invention, and the work required on it before it is considered saleable.

It is natural for an inventor to think that his brain-child is of paramount importance and value to the industry and that he should be compensated on the basis of estimated savings or some other basis that will yield him a high royalty. Unfortunately, even where substantial economies may be shown, consulting engineers and municipal officials resist the payment of high royalties and will seek alternate methods of treatment where high royalties are imposed. Further, attempts to invalidate a patent are encouraged by injudicious royalty demands. There is little resistance to the use of patented apparatus and processes in the sanitary field where royalties are nominal.

It is difficult to predict how much money an inventor can realize from the licensing of his patent. Taking extremes, the writer knows of one case where an invention was thought to have good possibilities but no royalties at all were earned. In another, payments totaling more than $200,000 were paid. Where an invention is considered a fairly good one, has good market possibilities, and is actively promoted, it is reasonable to expect royalty earnings in the range of $2,000 to $5,000 per year accruing to the inventor after an initial period of four to six years, during which time demonstration and sale promotional work must be carried on to commercially establish the invention. Proportionately, lower or higher royalties will be earned, of course, in the case of less important or more important inventions.

In some cases the agreement may provide that the inventor shall have the right to either cancel his agreement or to convert it into a non-exclusive agreement if stated annual royalties are not earned or equivalent payments made to him. In setting up such minimum amounts to avoid cancellation, due consideration should be given to the initial period required to build up sales momentum. Also, allowances should be made for lean years by permitting a carrying forward of earnings in excess of minimums and crediting the excess to future years.

A typical minimum earning schedule would be as follows:

Time	*Royalty*[1]
First A years of agreement	$0
$A + 1$ year of agreement	$X
$A + 2$ years of agreement	$Y
$A + 3$ and subsequent years of agreement	$Z

[1] To avoid cancellation.

In considering such cancellation provisions in an agreement, it would be well for an inventor to consider that, except under very unusual circumstances, it is unwise for the inventor to cancel his agreement if the licensee company can show that it has been active in attempting to sell his invention. If one company fails in its sales efforts, another would be very reluctant to undertake the expense and effort entailed in trying to sell what is equivalent to a dead horse.

With the royalty question settled, details of an agreement must then be worked out so that questions most likely to arise later will be anticipated. Companies interested in acquiring inventions most usually prepare such agreements in detail. The inventor should consult with a competent attorney in this matter so that he may be certain that his interests are protected.

Usual provisions of the average agreement comprise paragraphs relating to a description of the invention, warranty of ownership, grant of license, improvements, patenting, commercialization, assistance by inventor,

royalties, accounting, trade marks, litigation, name of invention, term of agreement, diligence, termination, arbitration, notices, assignments and interpretation.

Although all of these provisions are important, a few points concerning some of them deserve special mention because of their special significance. One relates to the license grant. Invariably a company acquiring a license insists on obtaining an exclusive right. Without such a right there is no incentive for the undertaking of development, design, advertising, or selling expense to promote the invention, as other companies if licensed would unfairly gain by such work on the part of one organization without incurring any expense themselves. It is only in the case of patented, fully developed, and accepted inventions that non-exclusive licenses are likely to be sold. The license grant should also permit the granting of sub-licenses to other companies in the field. In the case of process or system patents such sub-licenses are often granted by the prime licensee so as to provide for competitive bids called for in most engineers' specifications. Such sub-licensing is of considerable value to the inventor, as it greatly broadens the market for his invention. Often a company desires to obtain rights beyond the borders of the United States, some even desiring world rights. Again, the license grant should make such provisions where applicable.

Exceptions also should be noted in the license grant. Usually, a municipal employee gives a free right to the city for which he works. This free right might be extended to counties in the case of county employees, or even to states where the inventor is a state employee. It is obviously ridiculous, however, to extend this to the entire country in the case of federal employees, because then there would be no United States license rights to sell. Consulting engineers may exempt from royalty payments jobs that they design, whereas privately employed inventors usually grant a free right to their employing company, its associated companies and affiliates.

The right to grant a free license is entirely apart from one's obligation to do so by virtue of employment contracts or other expressed or implied understandings. Engineers employed by most private companies are obligated by contract to turn their inventions over to their companies. The same is true in the case of staff members of a number of experiment stations maintained by colleges and universities. Certain federal employees are also so obligated. In certain other cases, the sole obligation is the conveyance of a shop right to the employing company or agency, whereby such an organization receives a free right to the invention for use only in its own plants. Before an inventor negotiates with anyone regarding his patent rights, he should determine his rights to enter into a license agreement and his obligations to grant shop rights.

This leads to the problems encountered in a joint ownership of a patent, such as often occurs where joint inventors file a patent application and retain interest in it. In such cases either party can use the patent, grant rights under it, or sell all or part of his equity in it without consulting the other party or sharing any proceeds received from such use, licensing or sale. Therefore, for their mutual protection, co-inventors should enter into an agreement between themselves when they make an invention so that any inequities will be avoided in connection with its sale. No equipment company will negotiate with a single joint owner for rights to such a joint invention if it wants an exclusive right unless such a prior agreement has been

entered into by the co-owners of the invention.

Where it is desired to obtain foreign patents on an invention, it is essential that there be no publication disclosing it before the first filing of a patent application here or abroad. In some countries, a public disclosure made one day prior to the filing date will invalidate the patents later obtained in those countries. Therefore, in an agreement it is necessary to restrict the inventor from making any unauthorized disclosures. The foreign situation also adds certain other complications in payments of royalties to inventors. The reason for this is that the withdrawal of funds from certain countries may be blocked by law so that it is not always possible to convert foreign royalties to United States funds. In such cases, royalties may be put at the disposal of the inventor in the foreign currency and in the foreign country if such a procedure is permitted by local laws. Due to high foreign patent cost, etc., foreign royalties are usually lower than those paid in the United States.

Litigation provisions in any agreement are varied. In one generally used form, the licensed company has the sole rights to institute or settle suits for infringement. Where royalty payments or minimum payments to avoid cancellation are relatively high, however, it is often provided that the inventor is required to abate infringements called to his attention and that royalty payments are withheld until the infringements are abated either by settlement or suit. It is remarkable how few suits for infringement have been instituted in the sanitary field since the well-known actions in the case of the activated sludge patents in the 1930's. This may be attributed to the reasonableness of the royalties charged and the willingness on the part of most manufacturers to license others in the field in the case of process and system patents. The erroneous opinion has often been expressed that a patent is not good until it has been upheld in a court action. The opposite is true. A patent is presumed valid until it has been held otherwise by the courts.

It is natural to inquire: "What is there to invent so that I may increase my income?" The answer is that the field is without limit. There is no item of equipment or process used in the field of sewage and waste treatment that cannot be improved. Witness the advances made in sludge digestion, trickling filters, and the activated sludge process during the past 25 years. Also note the more recent activities in these specific fields. Digestion periods of 30 to 60 days are giving way to 2- to 5-day detention, high-rate filters are becoming superrate filters, and 2-hr. activated sludge treatment is being shortened to mere minutes. However, relatively few important advances have been made lately in the fields of screening, grit removal and sedimentation. Sludge concentration and dewatering devices still leave much to be desired. The treatment of industrial wastes is still a virgin field. Plant operators, especially, have excellent opportunities to test out process modifications that have patent possibilities. Not only can they gain by such work, but municipalities employing them can also benefit by any improvements resulting.

Appended is a list of United States patents covering the field of sewage treatment and issued within the past 25 years. Although these patents cover all phases of treatment, this list is by no means a complete one, especially in regard to apparatus. A large number of these patents have been used commercially, some to a considerable extent. Reference to these patents may be of value to workers in this field of activity; copies may be obtained from the Commissioner of Patents, United States Patent Office, Washington, D. C., for $0.25 each.

Summary

In lieu of a summary, the following "do's" and "don'ts" are offered for the consideration of those who may be in a position to make inventions.

Do's

1. Make a written record of the invention as soon as possible and keep notes on the development of the invention.
2. If a co-inventor, make an immediate agreement regarding the sale, etc. of the invention.
3. Decide whether to market the invention oneself or through an equipment manufacturer.
4. If it is desired to obtain one's own patent, consult a patent attorney promptly.
5. If it is desired to have the invention handled by a manufacturer, contact the one selected. The manufacturer should be the one it is believed will do the best job and in whom the inventor has complete confidence.
6. If the idea is of interest to the manufacturer, arrive at a basis of compensation for the invention.
7. Before an agreement is signed submit it to one's own attorney for review.
8. Co-operate in every way with the licensee; the interests of both the inventor and the licensee are the same in regard to making as much as possible from the invention.

Don'ts

1. Don't rush into print. By doing so one's chances of obtaining patents may be jeopardized.
2. Don't try to market the invention personally without considerable financial backing and/or an independent income.
3. Don't be discouraged by one or two turn-downs without good proof that the idea is old.
4. Don't expect to become wealthy from the royalties earned from the invention.
5. Don't try to act as one's own attorney, either in regard to patents or contracts. A lawyer wouldn't be hired to design a sewage treatment plant, so why think that an engineer can competently do patent and legal work?
6. Don't become discouraged if it appears that it's taking a long time to market the invention. Development, design and sales promotion work often drag on for three to five years or more before a machine or process is accepted in the sanitary field.

(Appendix on following page)

APPENDIX—A SELECT LIST OF U. S. PATENTS RELATING TO THE SEWAGE TREATMENT FIELD

Number	Inventor	Date of Issue[1]	Subject[2]
Re22,199	C. Nordell	2/20/54	Screenings comminuter
2,106,851	C. Nordell	2/1/54	Combined screen and comminuter
1,939,636	W. Weber	12/12/33	Mech. grit chamber
2,025,722	T. Camp	12/31/35	Flow control means
1,982,246	A. Fischer	11/27/54	Sludge thickening
2,089,162	R. Goudey, S. Bennett	8/3/37	Chlorination-thickening
1,605,596	W. Langelier	11/2/26	Floceulating unit
1,803,451	M. Smith	1/3/33	Transverse floc. unit
Re21,940	G. Darby, W. Weber, A. Fischer	11/11/41	Floc.-clarifier
2,110,721	A. Fischer	5/8/38	Raw sewage floc.
2,185,785	J. Dorr, W. Weber, G. Darby, E. Roberts	1/2/40	Clarification
2,355,760	H. Trebler	8/5/44	Dual-purpose clarifier
Re18,386	M. Tark	5/28/29	Drag clarifier
1,802,726	M. Levine	4/28/31	Backwash tr. filter
2,065,123	J. Downes	12/22/36	Tr. filt.-chem. precip.
Re22,444	C. Shook	11/2/37	Recycling around tr. filter
2,141,979	H. Halvorson, R. Smith	12/27/38	High-rate filter
2,142,196	L. Langdon	1/3/39	Alternating tr. filters
2,168,208	H. Jenks	8/1/39	High-rate filter
2,196,840	M. Singleton	4/9/40	pH adjust. ahead of filt.
2,200,580	M. Pruss	5/14/40	Forced aeration tr. filt.
Re22,144	O. Ward	10/7/41	Recirc. from final clar. to tr. filter
2,317,782	M. Levine	4/27/43	Backwashed tr. filter
2,340,842	D. Reybold, A. Fischer	2/1/44	Tr. filt. around clarifier
2,366,917	M. Levine	1/9/45	High-rate and low-rate filter
2,529,295	J. Hood	11/7/50	Pre-aeration and tr. filter
1,700,722	K. Imhoff	1/29/29	Wasting act. sl. to prim. clar.
1,904,916	J. Coombs	4/18/33	Act. sludge reaeration
2,154,132	E. Mallory	4/11/39	Control act. sludge
2,225,437	C. Nordell	12/17/40	Act. sludge control
2,337,384	R. Gould	12/21/43	Step aeration
2,349,390	S. Tolman	5/23/44	Floc. with act. sl.
2,363,176	J. Gunz	11/21/44	Act. sl. contact clarifier
2,370,974	L. Langdon	3/6/45	Pre-aeration clarifier
2,391,494	J. Walker	12/25/45	Bio-activation
2,394,413	J. Walker	2/5/46	Act. sl. effl. recirc.
2,404,223	A. Durdin	7/16/46	Biol. clar. with act. sl.
2,419,492	W. Green	4/22/47	Mixed liq. recirc. to primary clar.
2,436,584	J. Logan	2/24/48	Mixed liq. recirc. to aerator
2,477,459	E. Kelly	7/26/49	Pre-aeration clarifier
2,479,403	T. Powers	8/16/49	Jet aerator
2,492,486	A. Kivari, E. Kelly	12/27/49	Two-stage pre. aer. clar.
2,517,792	L. Kraus	8/8/50	Act. sludge control
2,027,370	F. Currie	1/14/36	Aerator-clarifier
2,008,507	W. Laughlin	7/16/35	Aerobic clarif. with tr. filter
2,114,601	W. Laughlin	4/19/38	Aerobic clarif. with tr. filter
2,562,510	H. Schlenz	7/31/51	Aerobic clarif.
2,465,658	F. Nussberger	3/29/49	High solids activation
2,559,462	M. Pirnie	7/3/51	Oxygen for act. sl.
1,743,550	K. Imhoff	1/14/30	Contact aerator
1,820,977	K. Imhoff	9/1/31	Contact aerator
1,991,896	C. Hays	2/19/35	Contact aerator
1,543,154	C. Fox, W. Davis	6/23/25	Garbage digestion
1,717,100	J. Downes	6/11/29	Floating cover
1,722,945	M. Pruss	7/30/29	Digester mixer
1,838,475	A. Buswell	12/29/31	Top. liq. recirc.
1,904,246	G. Ornstein	4/18/33	Dig. chem. sludge
1,912,595	H. Schlenz	6/6/33	Floating cover with mixer
1,925,679	J. Skinner	9/5/33	Clarifier-digester
1,938,647	G. Earp-Thomas	12/12/33	Aerobic digestion
1,963,591	H. Heukelekian	6/19/34	Thermophilic dig.
1,987,888	H. Babbitt, H. Schlenz	1/15/35	Tray digester
1,892,688	C. Keefer, F. Wachter	1/3/33	Dig. and clar. mech.
2,064,529	A. Fischer	12/15/36	Two-stage digestion
2,190,598	A. Fischer	2/13/40	Two-stage thermo. dig.
2,274,953	F. Downes	3/3/42	Tray digester
2,335,562	F. Downes	11/30/43	Tray digester
2,359,004	H. Schlenz, Cox	9/26/44	Supernatant treater
2,458,163	C. Hays	1/4/49	Supernatant treatment
2,516,076	H. Schlenz	7/18/50	External heating
2,520,540	W. Green	8/29/50	Scum breaker
2,174,873	J. Downes, T. Komline	10/3/39	Sludge freezing
1,999,973	A. Genter	4/30/35	Elutriation
2,259,688	A. Genter	10/21/41	Elutriation
2,528,649	A. Genter, C. Kennedy	11/7/50	Elutriation
2,293,028	A. Fischer	8/18/42	Elutriation
1,986,332	A. Fischer	1/1/35	Mixed sludge filt.
2,095,303	A. Wright	10/12/37	Cord filter
2,652,927	T. Komline	9/22/53	Spring filter

[1] Date of issue for reissue patent is given as the date of issue of the original patent.

[2] Subject titles are for identification only, and do not purport to define scope, etc., of the patents listed.

Industrial Wastes

PROCESS WASTES FROM CHEMICALS MANUFACTURE *

By George F. Jenkins

Engineering Department, Carbide and Carbon Chemicals Co., South Charleston, W. Va.

Every day one comes upon evidence of the great interest which the public has regarding air and water pollution. This interest naturally finds expression in the newspapers, which often dramatically express the problems confronting industry in the matter of industrial waste elmination.

Industry should consider itself fortunate that there is this wonderful medium—the press—by which it can get across to the public the true story of what it is doing about waste abatement. If improperly used, the consequences can be serious. In the Great Kanawha Valley of West Virginia, however, it can justifiably be said that relations of the Carbide and Carbon Chemicals Co. with the press and public have been excellent. In one newspaper, for example, have appeared several series of feature articles on both air and water pollution. A recent one (1), entitled "Save Our Streams," stated as follows:

> Carbide, too, has a good pollution abatement program. When I visited Carbide in 1951 to get information for "Shame of Our Streams," I was reminded of a hound pup my neighbor owned. This pup was anxious to do right—but its feet were too big.
>
> Now things are different. The Carbide pollution abatement program is beginning to mature. Pollution fighters now know what the problem is, what they're going to do about it—and where the money is coming from.

Much of the work still is devoted to preliminary construction and design—foundation work for the big cleanup that is yet to come. For instance, Carbide has spent $344,000 during the past year just to collect the waters containing process wastes from Blaine Island and bring them to a central point. These wastes formerly went into numerous main sewers where they mixed with storm water and enormous volumes of cooling water.

At the Institute Plant of Carbide, a total of $640,000 will be spent within the next year to separate wastes from uncontaminated cooling water.

This separation and collection program has not reduced pollution—the wastes still flow directly into Kanawha River. But, obviously, no treatment method could be applied to the process wastes while they were diluted in millions of gallons of cooling water. So the costly new sewer system had to be installed before pollution reduction could begin.

Design work for three more separation projects has been completed. These are scheduled to be in operation by the summer of 1956, and may cost nearly $1,000,000 more than the amount already expended.

Meanwhile a pilot treatment plant on Blaine Island, which cost almost $100,000 to construct, is operating 24 hours a day, seven days a week. It already has been established in Carbide's laboratories that biological treatment (similar to that used in city sewage treatment) can be adapted to many of Carbide's organic wastes.

In the biological treatment method, bac-

* Presented at 27th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Cincinnati, Ohio; Oct. 11–14, 1954.

teria deliberately cultured for the purpose attack the organic wastes and reduce them to harmless materials. The new pilot plant, which went into operation less than 60 days ago, looks big but it will treat only two-tenths of one per cent of the wastes from the South Charleston plant.

Within a year, the pilot plant is expected to provide the information needed to design a plant to treat its huge volume of organic process wastes.

Carbide isn't depending entirely on the forthcoming biological waste treatment plant. Many of its units have built-in pollution abatement facilities. Design changes and process changes are being made all the time to reduce the amounts of pollutants reaching the river. At the same time, Carbide workers are being encouraged to avoid spills and needless discharge of waste materials to the river. Employees cooperate eagerly in this program. Carbide rates an "A" for effort.

Public Understanding Essential

The effects of this article and others are indicative of the continuing need to keep the public informed of what has or is being done. Yet, every day still brings startling examples of the great need that exists for improved understanding of the immense problems posed by pollution control, on the part of the people, the press, and in some instances on the part of public officials not directly connected with the control agencies.

For more than 20 years, experimental work has been going on in the laboratories and plants of Carbide and Carbon Chemicals Co. as part of a continuing program toward abatement of the industrial wastes discharged to the atmosphere and to the Kanawha River. That this problem is not a simple one can easily be understood. It is not the purpose of this paper to indicate that the problem is any worse for the organic chemical industry than for other industries, but each has its own individual and unusual circumstances, which differ materially from those of other industries and other locations.

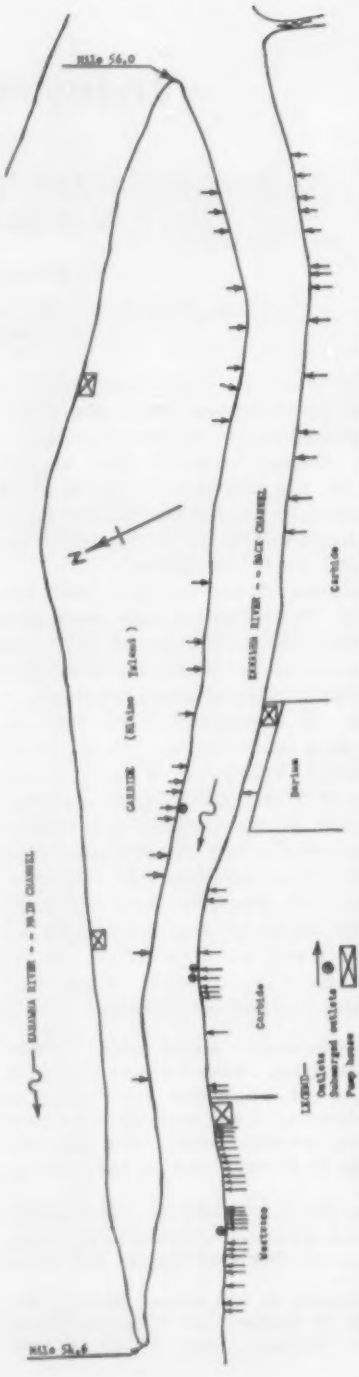

FIGURE 1.—Outfalls and water pumping stations, South Charleston plant, Carbide and Carbon Chemicals Co.

Operations Began In 1925

The South Charleston plant site of the Carbide and Carbon Chemicals Co. was leased on November 1, 1923, for a 5-year period. It was not until November 1925 that the plant was ready for the manufacture of ethylene glycol, on a scale of less than 4 per cent of the present rate at that location. Water was purchased from the adjacent plant of the Barium Reduction Corp. until 1927, at which time the Chemicals Company purchased Blaine Island and installed its own water pumping station. The growth of any chemical plant can be gaged by a number of key factors, among which the quantity of water used is a very significant item. As will be seen later, the quantity of water used is intimately connected with the waste disposal problem of the South Charleston plant. The total annual water usage of the South Charleston plant of the Carbide and Carbon Chemicals Co. has increased steadily from 0 in 1925 to the present rate of nearly 78,000 m.g. per year, which is equivalent to an average pumping rate of approximately 150,000 g.p.m. In the warm summer months, the pumping rate sometimes is as high as 180,000 g.p.m. and the installation of additional cooling water pumping capacity is under study. At the plant located at Institute, W. Va., just 10 mi. downstream from the South Charleston site, a similar quantity of water is pumped the year round.

Naturally most of this water is used for removal of heat in condensers, coolers, and so forth. However, as previously stated, this quantity is intimately involved with the waste disposal problem inasmuch as all liquid waste material has been discharged to the same sewers in which the waste cooling water is conveyed back to the river. After the purchase of Blaine Island in 1927 and during the subsequent plant expansions, it was found most expedient to discharge the liquid effluents from each manufacturing unit through individual outfalls rather than to collect them all in one large sewer for discharge at a single point. Therefore, there evolved a multiplicity of outfalls along the back channel of Blaine Island (Figure 1). The main channel of the Kanawha River flows along the north side of Blaine Island and the two pump houses supplying cooling water to the entire plant are located on the north bank of the island. The waste cooling water and all liquid process wastes are discharged through more than 60 outfalls indicated by the arrows drawn on both sides of the back channel. It is apparent, therefore, that before any ultimate treatment can be accomplished, a considerable expenditure of money will be involved in isolating all of the individual wastes and collecting them in one single interceptor. For this reason it is obvious that extreme measures must and are being taken to effect the maximum reduction at the source that can be achieved.

Outfall Sampling Inaccurate

A still further problem is posed by this same multiplicity of outfalls from which the waste materials are discharged. Both the Company and the West Virginia State Water Commission are very interested in obtaining an accurate understanding of the effect the discharged wastes have on the ecology of the Kanawha River. For years an attempt has been made to evaluate this by means of B.O.D. determinations on samples taken from these outfalls. Recently, however, it has been rather conclusively proved that a satisfactory correlation between the total B.O.D. in the outfalls and that exhibited by the river could be obtained only by the following:

1. Installation of elaborate continuous proportional sampling equipment on nearly all of these outfalls.

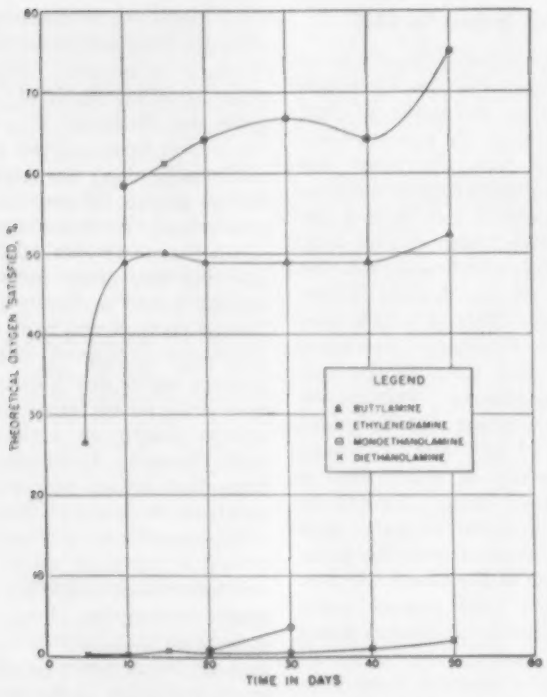

FIGURE 2.—Rate of biochemical oxidation of organic compounds.

2. Improvement of the degree of mixing of the effluent to avoid poor sampling in the event that heterogeneous mixtures are present.

3. Development of improved B.O.D. methods which will minimize the toxic effects of these waste materials.

Chemical B.O.D.'s Erratic

For some time data correlating the total B.O.D.'s of the individual outfall have been examined and compared. Several outfall studies have indicated that the total B.O.D. discharged to the river was approximately 30,000 lb. per day. On the other hand, surveys conducted by the Water Commission on the Kanawha River above and below the plant location have indicated that it may actually be several times this value. This poor correlation is believed due to the effects illustrated by B.O.D.'s of pure compounds. Some of these results are indicated in Figures 2, 3 and 4. These data have been more fully reported elsewhere (2) (3) (4).

The process wastes mixed with the used cooling water leaving through the many individual outfalls are in most cases sufficiently concentrated as to be essentially bacteriostatic, and even bactericidal. Samples of these liquids behave in much the same manner during the B.O.D. test as the samples of pure compounds illustrated in the slides. It is not until these wastes have been thoroughly diluted and mixed with the main body of water in the Kanawha River that they become amenable to biological oxidation. Investigation of this extremely complex subject is continuing in an effort to comply with the expressed wishes

of the West Virginia State Water Commission.

River Flows Erratic

The question may well be raised, on the other hand, as to why an accurate estimate of the B.O.D. load can not be obtained through the simple procedure of conducting river surveys. Superficially, of course, this would seem to be the proper procedure since interest centers in the effect of the waste materials on the river itself. Numerous surveys have been made and undoubtedly many of them are reasonably accurate. However, they are extremely tedious and are subject to so many uncontrollable influences that even the best results are open to question because of unpredictable variables. Figure 5, for example, illustrates the extreme variations in flow that may take place during a given month. As can be seen, a 10-fold variation in flow is not uncommon and the variation can often be greater. The low values during the months of July through September constitute a real problem for all the industries and municipalities located along the river.

Figure 6 illustrates an even worse condition which can make a survey seriously subject to error. The three

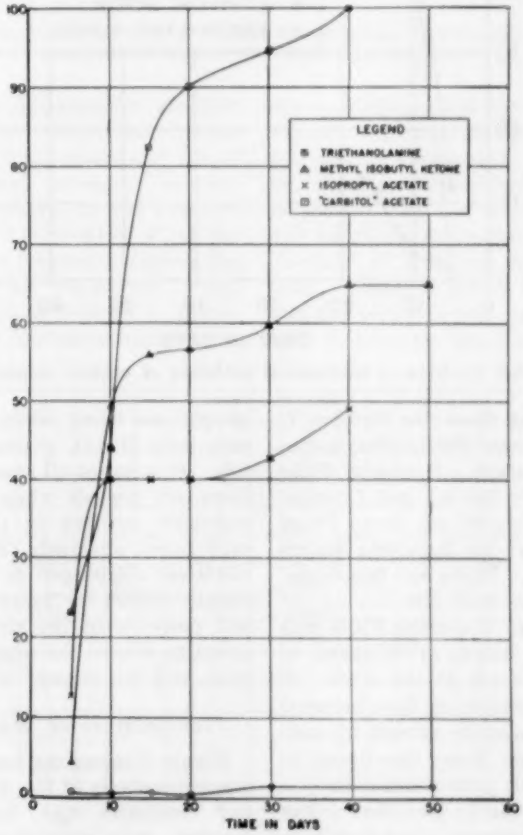

FIGURE 3.—Rate of biochemical oxidation of organic compounds.

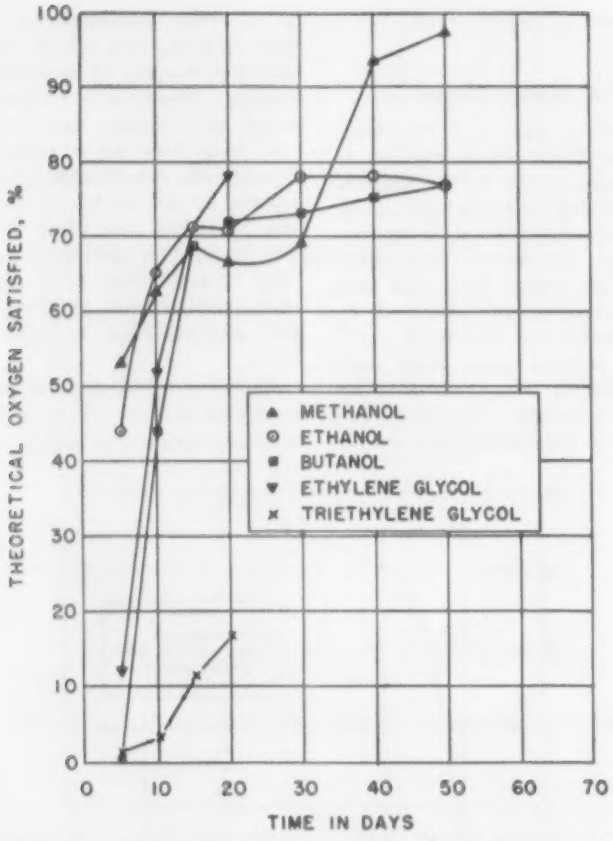

FIGURE 4.—Rate of biochemical oxidation of organic compounds.

curves represent flows for October 7, 1950, at Kanawha Falls, Charleston, and Point Pleasant. Kanawha Falls is approximately 100 mi. and Charleston approximately 58 mi. above Point Pleasant, where the Kanawha enters the Ohio River. There are two dams, one at London and the second at Marmet, between Kanawha Falls and Charleston. A third, at Winfield, is in the lower stretch of the river. A great daily variation in flow between these several points is caused by controlled discharge from the dams in response to peak power demands.

Therefore, it can be seen that unless instantaneous, accurate river flow data can be obtained at the moment river samples are being taken, wholly erroneous total B.O.D. evaluations will result. It is not at all inconceivable that there are periods when there is substantially no flow in the river. At such times, obviously, the total waste materials discharged to the river will simply collect in large pools, which will move down the river in massive quantity when the dams are again open and the storage released.

Temperature of Water Raised

Figure 7 shows the temperature frequency analysis of the Kanawha River and indicates the heat imparted through the generation of electric power at the coal-burning Cabin Creek

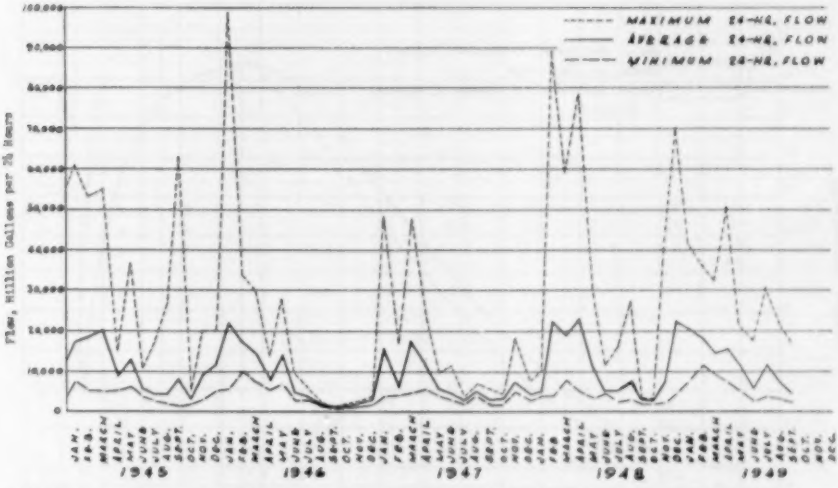

FIGURE 5.—Kanawha River flow at Patrick Street bridge (Charleston, W. Va.) from Jan. 1945 to Sept. 1949. (Data from USGS.)

station of the Appalachian Electric Power Co. The temperature data, taken at points 5 mi. apart and representing statistical averages, indicate that the temperature, on the average, is raised from 79.5° to 81.5° F. at the point of greatest frequency during the period covered by the survey. This situation is of great interest to industries at South Charleston because the power company has recently installed a second station at Glasgow, located 25 mi. east of Charleston, with 400,000-kw. capacity. It is therefore natural to assume that the river temperature will be raised approximately an additional 2° F. with this station in operation. Concern arises from the fact that not only will this temperature rise tend to decrease the dissolved oxygen

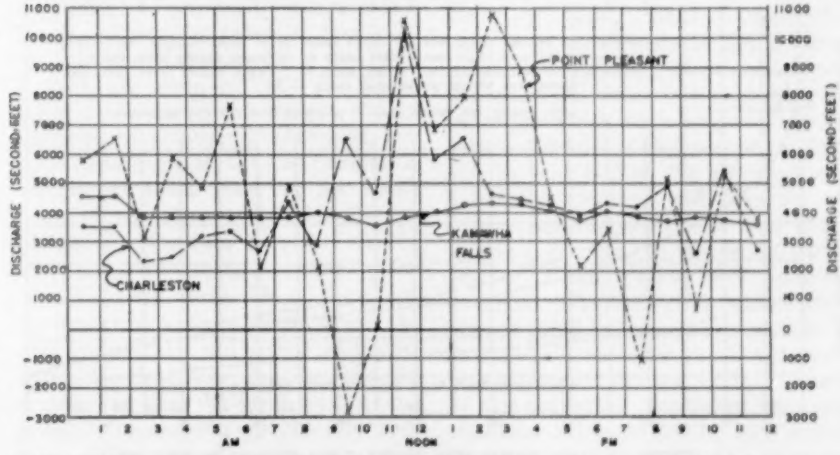

FIGURE 6.—Kanawha River flow at Kanawha Falls, Charleston and Point Pleasant on October 7, 1950.

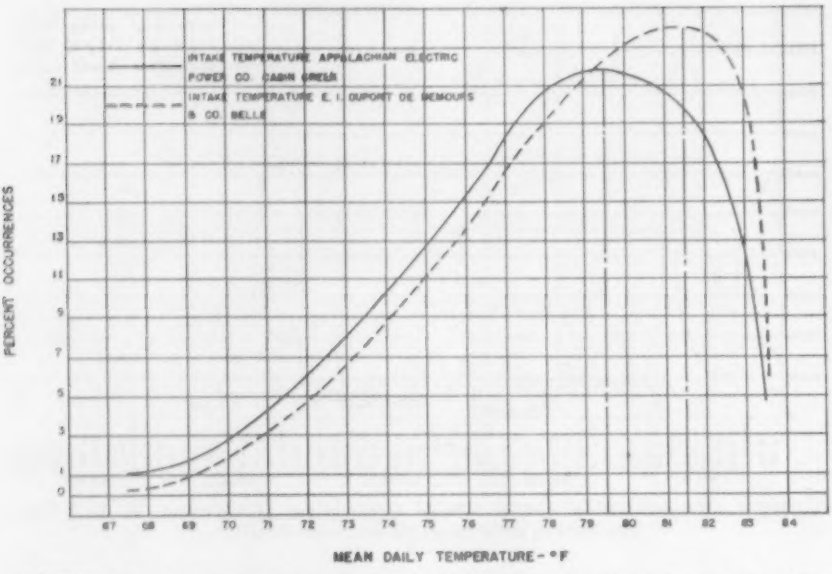
INTAKE TEMPERATURE APPALACHIAN ELECTRIC POWER CO CABIN CREEK
INTAKE TEMPERATURE E. I. DUPONT DE NEMOURS & CO BELLE
PERCENT OCCURRENCES
MEAN DAILY TEMPERATURE - °F

FIGURE 7.—Temperature-frequency analysis for Kanawha River above and below Cabin Creek power station, June–August (1947–1949).

in the water, but it will also seriously reduce the capacity of condensing and cooling equipment which depend on river water for heat removal. Additional studies of this problem are now being made to enable industry to cope with it at the proper time. An attempt is being made to correlate this effect with the frequency of low flow (Figure 8) in an effort to predict its possible influence on future operation.

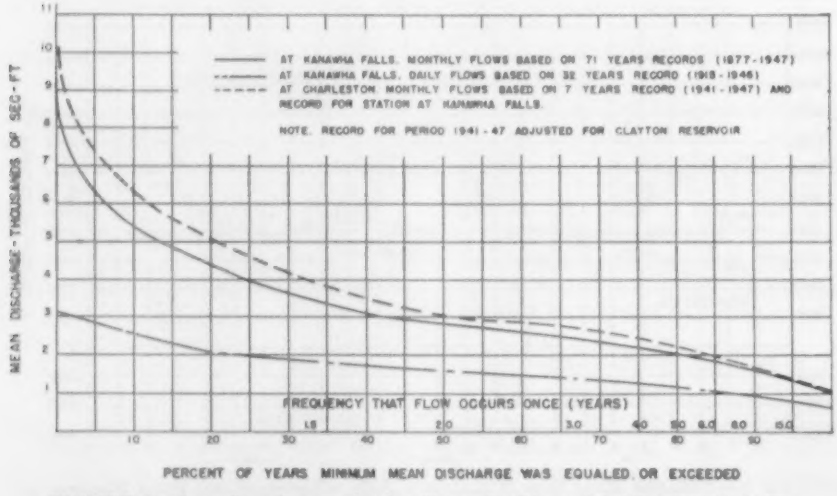
AT KANAWHA FALLS, MONTHLY FLOWS BASED ON 71 YEARS RECORDS (1877-1947)
AT KANAWHA FALLS, DAILY FLOWS BASED ON 32 YEARS RECORD (1913-1946)
AT CHARLESTON MONTHLY FLOWS BASED ON 7 YEARS RECORD (1941-1947) AND RECORD FOR STATION AT KANAWHA FALLS.
NOTE. RECORD FOR PERIOD 1941-47 ADJUSTED FOR CLAYTON RESERVOIR
MEAN DISCHARGE - THOUSANDS OF SEC-FT
FREQUENCY THAT FLOW OCCURS ONCE (YEARS)
PERCENT OF YEARS MINIMUM MEAN DISCHARGE WAS EQUALED OR EXCEEDED

FIGURE 8.—Low-flow frequencies for Kanawha River, July–October, inclusive.

TABLE I.—Analyses of Kanawha River; June 6, 1951

Sample No.	pH	Alk. (p.p.m.)		B.O.D. (p.p.m.)	Chem. Oxy. Cons. (p.p.m.)	D.O. (p.p.m.)	Chlorides (p.p.m.)	Sulfates (p.p.m.)	Hardness[1] (p.p.m.)	Total Solids (p.p.m.)	N[2] (p.p.m.)
		M.O.	Ph.								
(*a*) Above Plant (Temp., 21.3° C.)											
1	7.1	33	−3	7.0	27	7.0	2.3	5.8	45	115	1.52
2	7.4	34	−2	1.4	25	6.4	2.3	6.0	48	95	1.58
3	7.3	37	−2	2.2	25	7.9	2.2	10.0	55	98	1.76
4	7.5	39	−2	2.1	23	8.3	2.1	9.0	54	105	1.46
5	7.5	36	−1	2.0	25	8.0	2.1	10.0	53	95	1.46
(*b*) Below Plant (Temp., 22° C.)											
1	7.2	32	−3	5.1	Nil	6.4	4.3	10.3	53	92	1.82
2	7.2	36	−3	3.9	27	6.9	4.0	9.8	52	80	1.75
3	7.3	36	−3	4.8	25	7.1	4.1	9.5	54	90	1.82
4	7.1	35	−3	6.6	20	7.2	4.7	9.5	55	102	1.70
5	7.3	39	−1	9.4	12.5	7.0	50.0	10.7	125	283	1.70

[1] As $CaCO_3$.
[2] As NH_3.

Pollution Channels

Another serious difficulty encountered in the matter of making stream surveys arises from the great tendency for materials discharged to the river to "channel" for many miles before becoming intimately mixed with the main body of the stream. This condition can be very pronounced and makes the B.O.D. results of river survey samples extremely questionable. Results of samples taken at two locations on the Kanawha River on June 6, 1951, are given in Table I. Those taken above the plant indicate fairly uniform distribution of chlorides, but there was high B.O.D. in Sample 1, which was taken close to the north bank of the river. This can be explained by the fact that the city of Charleston discharges its wastes principally on the north side of the river. In the samples taken 3.8 mi. below the plant, reasonable uniformity exists between the first four samples; but the fifth, taken near the south bank of the river, indicates a high chloride content. This is explained by the fact that both the Carbide and Carbon Chemicals Co. and the Westvaco Chlorine Products Co. discharge all of their waste material along the south bank. Any attempt to go below the 3.8-mi. sample point would reach the site of the Institute plant; of course, samples taken there would be complicated by the discharges there.

For the more productive side of the problem, it can be said that progress in the control of stream pollution is definitely being made. Naturally, since it is so difficult to get positive results by either outfall or stream survey analyses, there is no satisfactory record to which such progress can be referenced and compared. All that can be said is that the problems are being met squarely and that the results ultimately will be of such magnitude that even the poorest of methods of determination will indicate progress. Obviously, if a total of more than 100,000 lb. per day of B.O.D. is being lost to the river this must represent substance of real value in terms of raw materials. Assuming the usual relations between B.O.D. and actual pounds of organics, this quantity should represent approximately 60,000

lb. per day of organics, which at a value of $0.05 per pound would be equivalent to a loss of about $1,000,000 per year. Obviously, all of this material cannot be recovered as valuable product or by-product. The profit motive certainly must be minimized if the problem is to be approached realistically.

Profits From Wastes

This aspect has been thoroughly discussed at many of the industrial waste meetings on record. However, it is nonetheless a pleasure to report that through the proper engineering approach it has been possible on some occasions to derive benefit by recovery of materials previously lost to the river. Examples of this are of fairly recent occurrence. In the production of certain high-boiling chemicals, final purification is accomplished by evaporation under a pressure of less than 1 mm. Hg. It was generally accepted that after the vapors were condensed and cooled, in the most efficient type of condenser with minimum frictional loss, the vapor pressure would be so low that vent losses through the steam jet vacuum pumps would be negligible. However, lengthy operating tests indicated that losses were occurring and as a consequence the direct contact barometric condensers were replaced with surface types. One may well imagine the satisfaction derived when it was found that the losses recovered are even greater than anticipated. Because of this finding, literally dozens of the direct contact type barometric condensers have been replaced with the surface types. In many cases the losses which will be recovered will be insignificant from a profit standpoint. However, in the aggregate there will be a substantial recovery of materials now lost to the sewer and which should represent a significant reduction in the B.O.D. loading of the river.

There is another problem in the disposal of waste material which is not actually a stream pollution problem, but which nevertheless is of great concern and cost. This is the disposal of fly ash produced by the combustion of pulverized coal for the generation of steam. Some of the boilers in the South Charleston plant, for example, are equipped to generate steam by pulverized coal combustion, which at capacity will consume as much as 1,000 tons per day if operated entirely on coal. All are equipped with electrostatic precipitators, which collect at least 90 per cent of the fly ash leaving the boilers. By actual measurement it has been determined that the ratio of recovered ash to coal consumed is approximately 0.2225. The settled ash has a density of 1,100 lb. per cubic yard, so the company is faced with the task of disposing of more than 100,000 cu. yd. of fly ash per year. To this end the ash, suspended in water, is piped to various low spots throughout the valley where the ash settles out and is compacted while the water flows back into the river. Examination of this effluent has shown it to be wholly unobjectionable as far as its effect on the Kanawha River is concerned (5). All of the areas in current use are nearly full and a new site is being developed at South Charleston which should last 50 years.

Acrylonitrile Plant Wastes

Efforts toward abatement and prevention of air and water pollution are expended not just on old and existing processes. All new installations are now designed with full attention to adequate waste control and treatment operations. An outstanding example of this relates to the acrylonitrile plant installed at the Company's works at Institute, W. Va. The project was publicly announced in 1953. Shortly thereafter specifications for the full treatment of all effluents from these operations were submitted to the State Water Commission (6). In part, the report outlined policies, as follows:

Extraordinary and costly steps have been taken in the design and construction plans for the Acrylonitrile Plant to prevent any release of toxic materials. The additional costs incurred in comparison to the cost of a plant designed in accordance with normal practices will approach $1,000,000. The special design features include among others:

1. Closed cycle process water systems with all streams subjected to stripping distillations.
2. Two separate systems for treatment of the stripped process water streams to destroy (by chlorination and by other methods) any toxic contaminants.
3. Retention tanks to receive the treated process water streams and permit examination and treatment before discharge to the process waste sewer.
4. Facilities for retreatment when necessary.
5. Curbed concrete pavement under all processing equipment and storage tanks with drainage pipes to carry all spillages, fire water, rain water, etc., from these areas to the retention tanks for examination before they are released to the sewer.
6. Facilities for handling contaminated drainages collected in these tanks by either chemical treatment or return to the processing equipment.

These facilities are constantly scrutinized to ensure that they are adequate and fully accomplish their intended objective. The installation has received the full approval of the Commission. The same procedure is being followed for an installation for the manufacture of acrolein, now under construction.

The pilot-plant experimental program aimed at prevention of discharge of phenolics, which can be high taste- and odor-producing factors in public water supplies, is described elsewhere (7).

W. Va. Water Commission

These and other methods under continual review by management will enable the Carbide and Carbon Chemicals Company ultimately to meet with the minimum requirements for the Kanawha River which have been adopted by the West Virginia Water Commission. These are set forth by the Commission as follows:

No sewage, industrial wastes or other substances allowed to enter any of the waters of the state shall cause therein or materially contribute to any of the following conditions thereof:

1. Distinctly visible floating or settleable solids, scum, foam or oily sleeks of unreasonable kind or quantity.
2. Objectionable bottom deposits or sludge banks.
3. An unreasonable degree of treatment for the production of potable water or prevent the production of potable water by modern water treatment processes as commonly employed; objectionable odors in the vicinity of the waters.
4. Toxic or poisonous conditions that affect man, animal or fish life.
5. The dissolved oxygen concentration to be less than 3.0 parts per million at the point of maximum depletion.

It is not believed that these objectives are impossible of attainment, although it is obvious that concerted action is imperative on the part of all industries and municipalities in the Kanawha Valley.

Laboratory investigations are currently studying the comparative advantages of three methods of disposal by biological methods. These are: (a) the high-rate trickling filter; (b) the activated sludge method; and (c) the dispersed seed method described by Heukelekian (8).

Concurrent with the aforementioned laboratory studies, gaging and sampling stations have been set up on the back channel of the Kanawha River in order to cooperate with the West Virginia Water Commission in attempting to establish a reliable means of evaluating the total B.O.D. of the wastes discharged to the river. This computation cannot be based on an estimate of the materials accounted for in the plant materials balance be-

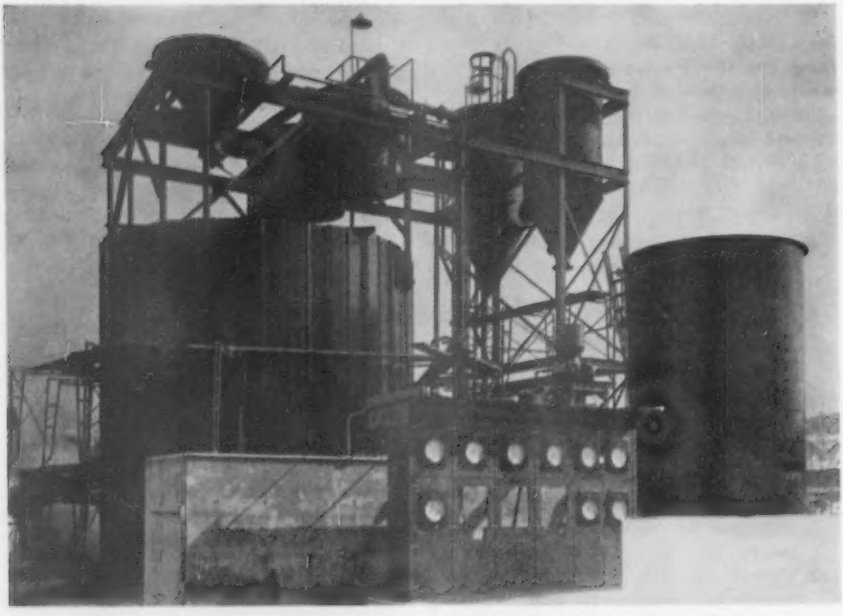

FIGURE 9.—Pilot plant for study of contaminated effluents treatment.

cause the oxygen equivalent of the constituents of the many diverse streams entering the river cannot be evaluated. The objective of such a reliable river sampling and surveying method would be to establish a yardstick, so that there is a firm basis for evaluating progress and improvement in the matter of stream pollution abatement.

Pilot Treatment Plant

Before serious thought can be given to abatement of the pollution by treatment beyond reduction at the source, the myriad streams must be segregated from the uncontaminated effluents, such as cooling water, storm water, etc. The polluted streams can then be directed to an interceptor sewer, which will convey them to a central point for mixing, neutralizing, examination and treatment. The first stages of this program are already completed. Operation of a pilot plant or semi-works unit, which will be an experimental laboratory for evaluation of various methods of chemical and biochemical treatment of the irreducible residues, was first recently begun. The data obtained here will be employed for the design of an eventual, full-scale treatment plant to provide the required degree of reduction of the B.O.D. load discharged to the Kanawha River. Figure 9 is a general view of the pilot plant, which contains a 20-ft. diameter trickling filter.

Summary

In summary, the following statement on pollution which appears in the "Facts Book" of the Manufacturing Chemists' Association (1953) is most appropriate:

> Wherever there is a concentration of human activity, waste products from manufacturing operations may create a pollution problem. When the capacity of air and water to assimilate these wastes satisfactorily is overtaxed, all sources contributing to the nuisance must reduce their emission of gaseous and liquid by-products to unobjectionable levels.

The control of water and air pollution is a continually changing problem due to the constant change of industrial processes. Furthermore, because of differences in weather conditions, terrain and the polluting substances, there is no standard formula to solve an individual area's problem. Study of each area's unique situation must precede remedial action. Conscious of their responsibilities as good neighbors, chemical manufacturers are constantly studying conditions in their localities to lessen pollution.

The chemical industry is playing a leading role in the prevention and abatement of air pollution by the following activities:

1. Chemical companies engineer new plants so that waste products will not be objectionable.
2. Chemical companies are spending more than $1 million a year in research to study the nature of air and water pollution and processes for minimizing pollution.
3. Chemical companies are spending at least $10 million annually to install new devices to abate pollution in older plants and to operate existing equipment.
4. The chemical industry, through the Air and Water Pollution Abatement Committees of the Manufacturing Chemists' Association, is working closely with other industries and regulatory officials toward the solution of regional problems.
5. The chemical industry is taking a leading part in exchanging technical information on pollution control. Through the MCA it sponsors conferences and issues informative publications on recent technical developments in all phases of pollution control.

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METABOLISM OF LOW MOLECULAR WEIGHT ALCOHOLS BY ACTIVATED SLUDGE

By Ross E. McKinney and John S. Jeris

Assistant Professor of Sanitary Engineering and Research Assistant, respectively, Department of Civil and Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Rapid expansion of the synthetic chemical industry since World War II has created many new problems in the field of waste disposal. The engineer has been confronted with the problem of disposing of organic chemicals foreign to the organic compounds found in domestic sewage and normally considered toxic to the microorganisms in the various biological treatment units. By the process of acclimation the engineer has found that it is possible to develop biological growths similar to those in domestic sewage treatment plants, but composed of the microorganisms capable of utilizing the synthetic organic compounds rather than the microorganisms which prefer sewage. The vast number of different types of microorganisms found in nature offers the synthetic chemical industry the means for establishing biological systems for disposing of their dilute organic wastes.

Although considerable research has been carried out on the development of biological treatment processes for synthetic chemical wastes (1–7), nothing has been done to determine the fundamental nature of the systems or the reactions taking place. This study was carried out to furnish basic information on the metabolism of the simple alcohols, one to four carbon atoms per molecule, by activated sludge.

[a] Presented at 26th Annual Meeting, New England Sewage and Industrial Wastes Assn.; Fairfield, Conn.; Oct. 28, 1954.

Theoretical Considerations

The metabolic systems of the microorganisms in any waste disposal plant follow definite pathways. For the most part, the metabolic pathways are relatively simple and interrelated for the various types of organic compounds utilized. Carbohydrates, fats, proteins, alcohols, aldehydes, ketones, organic acids and the other organic compounds have the same basic pathways of metabolism but have their own distinct preliminary pathways. On the preliminary metabolic pathways the complex organic matter is broken down by hydrolyses and occasionally by a combination of hydrolyses and oxidation to form the basic compounds, which then enter into the basic metabolic pathways. Once within the basic metabolic pathways, part of the organic matter is broken down still further to furnish the energy required by the cell while the remaining organic matter is used to synthesize new cell tissue.

The preliminary pathways for low molecular weight alcohol metabolism have been shown to follow the pathway of chemical oxidation (8) (9). The normal alcohols and isobutanol are oxidized first to aldehydes and then to acids; isopropanol and 2-butanol are oxidized to the corresponding ketones and then to acids. It is at the point of oxidation of the acid that chemical oxidation splits from biological oxidation. Chemical oxidation breaks the acid directly to carbon

dioxide and water, whereas biological oxidation is brought about through introduction of the acid into the tricarboxylic acid cycle. The exception is formic acid, which is believed to be oxidized along the path of chemical oxidation, directly to carbon dioxide and water.

The basic metabolic pattern for aerobic bacteria is the tricarboxylic acid cycle, also known as the Kreb or citric acid cycle (Figure 1). The tricarboxylic acid cycle is the energy-producing mechanism for the aerobic bacteria. As the organic matter is changed from compound to compound around the cycle, energy is made available for the normal cell functions, such as synthesis and motion. Organic compounds which are structurally related to any of the members of the energy cycle can readily enter into the cycle and be rapidly converted to energy. Compounds not directly related to members of the tri-

TABLE I.—Alcohols, Aldehydes, Ketones and Acids Used in the Warburg Respirometer Studies

Sludge Acclimated to	Organic Substrate	Chemical Structure
1. Methanol	Methanol	CH_3OH
	Formaldehyde	CH_2O
	Formic acid	$HCOOH$
2. Ethanol	Ethanol	CH_3CH_2OH
	Acetaldehyde	CH_3CHO
	Acetic acid	CH_3COOH
3. n-Propanol	n-Propanol	$CH_3CH_2CH_2OH$
	Propionaldehyde	CH_3CH_2CHO
	Propionic acid	CH_3CH_2COOH
4. Isopropanol	Isopropanol	$CH_3CHOHCH_3$
	Acetone	CH_3COCH_3
	Propionaldehyde	CH_3CH_2CHO
	Propionic acid	CH_3CH_2COOH
5. n-Butanol	n-Butanol	$CH_3CH_2CH_2CH_2OH$
	Butyraldehyde	$CH_3CH_2CH_2CHO$
	Butyric acid	$CH_3CH_2CH_2COOH$
6. Isobutanol	Isobutanol	$(CH_3)_2CHCH_2OH$
	Isobutyraldehyde	$(CH_3)_2CHCHO$
	Isobutyric acid	$(CH_3)_2CHCOOH$
7. 2-Butanol	2-Butanol	$CH_3CH_2CHOHCH_3$
	2-Butanone	$CH_3CH_2COCH_3$
	Butyraldehyde	$CH_3CH_2CH_2CHO$
	Butyric acid	$CH_3CH_2CH_2COOH$
8. Tert.-butanol	Tert.-butanol	$(CH_3)_3COH$
	Butyraldehyde	$CH_3CH_2CH_2CHO$
	Butyric acid	$CH_3CH_2CH_2COOH$

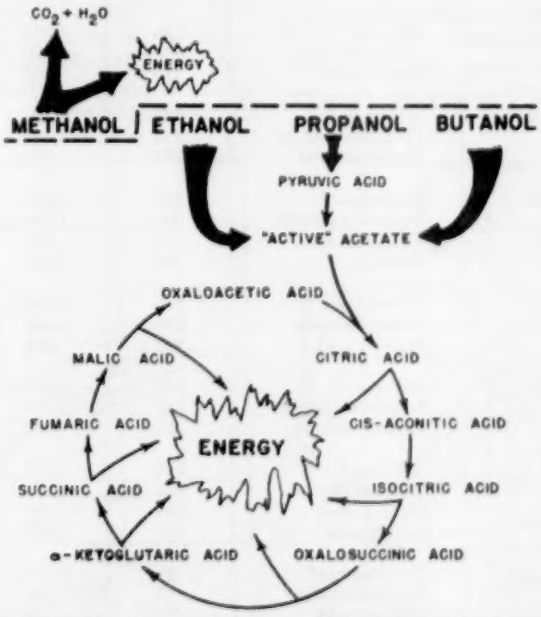

FIGURE 1.—Bacterial metabolism of low molecular weight alcohols and the tricarboxylic acid cycle.

TABLE II.—Concentration of Mixed Liquor Suspended Solids in Warburg Respiration Flasks During Oxidation Studies

Substrate Acclimated to	Suspended Solids (p.p.m.)
Methanol	670
Ethanol	1,100
n-Propanol	1,040
Isopropanol	790
n-Butanol	1,760
Isobutanol	1,240
2-Butanol	1,050
Tert.-butanol	170

carboxylic acid cycle must undergo structural rearrangement and changes to form a compound which can enter the cycle. Such compounds are normally broken down only slowly. The low molecular weight alcohols enter the tricarboxylic acid cycle as shown in Figure 1 through "active" acetate or pyruvic acid.

In considering metabolic pathways it must be remembered that this discussion concerns the over-all metabolic pathways in a complex microbiological population and not those of a pure culture of bacteria. The metabolic pathways of the complex microbiological system are the summation of the pathways of the individual species

TABLE III.—Oxygen Utilized by the Alcohol-Acclimated Activated Sludge after 23 Hours Aeration and the Theoretical Oxygen Required for Complete Oxidation of 500 P.P.M.*

Alcohol Acclimated to	Substrate Fed	Oxygen (p.p.m.)		Theoretical Oxidation (%)
		Utilized	Theoretical Requirement	
1. Methanol	Methanol	414	750	55
	Formaldehyde	41	533	8
	Formic acid	63	174	36
2. Ethanol	Ethanol	535	1,074	51
	Acetaldehyde	446	909	49
	Acetic acid	370	533	69
3. *n*-Propanol	*n*-Propanol	623	1,133	55
	Propionaldehyde	532	1,103	48
	Propionic acid	391	757	53
4. Isopropanol	Isopropanol	564	1,133	50
	Propionaldehyde	108	1,103	10
	Propionic acid	134	757	18
	Acetone	282	1,103	26
5. *n*-Butanol	*n*-Butanol	575	1,297	44
	Butyraldehyde	429	1,222	35
	Butyric acid	356	909	39
6. Isobutanol	Isobutanol	577	1,297	44
	Isobutyraldehyde	438	1,222	36
	Isobutyric acid	355	909	39
7. 2-Butanol	2-Butanol	744	1,297	58
	Butyraldehyde	467	1,222	38
	Butyric acid	393	909	43
	2-Butanone	807	1,222	66
8. Tert.-butanol	Tert.-butanol	28	1,297	2
	Butyraldehyde	7	1,222	1
	Butyric acid	73	909	8

* Corrected for endogenous respiration.

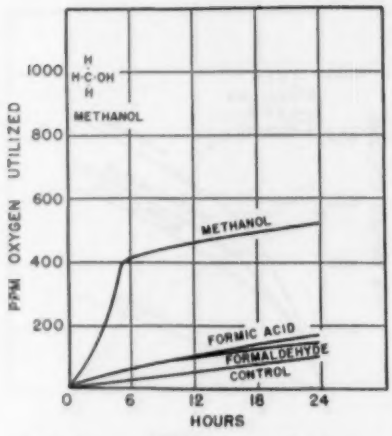

FIGURE 2.—Oxygen utilization of methanol-acclimated activated sludge and 500 p.p.m. substrates.

making up the microbiological population.

Procedures

Activated sludge systems were set up in 2.5-l. tubes in a thermostatically controlled water bath at 20° C. Each unit contained 1.5 l. of mixed liquor and was fed organic substrate once daily. The initial activated sludge was built up on a synthetic substrate consisting of 500 p.p.m. glucose, 500 p.p.m. nutrient broth, and the necessary inorganic salts to insure complete metabolism of the organic substrate. The source of microorganisms was contained in 100 ml. settled Boston sewage, which was used as seed daily during the acclimation period. Activated sludge was allowed to build up in the system for 10 days, then increasing amounts of the various alcohols studied were added and the glucose-nutrient broth concentration correspondingly reduced until after 22 days, when the units were being fed alcohol as the sole source of energy.

On the 24th day of operation a regular sludge wasting procedure was established. The operation cycle consisted of 23 hr. aeration followed by wasting 500 ml. mixed liquor, settling the remainder for 1 hr., wasting 500 ml. of the supernatant, and feeding 1,500 mg. of the alcohol in 1 l. of tap water. As soon as microbiological equilibrium was established, Warburg respirometer studies were made to determine the organisms' ability to metabolize 500 p.p.m. of the alcohol being fed as well as 500 p.p.m. of the corresponding aldehyde or ketone and

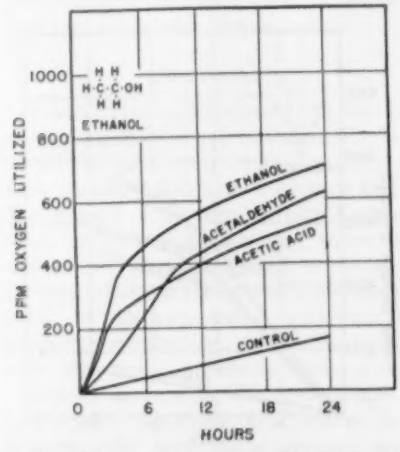

FIGURE 3.—Oxygen utilization of ethanol-acclimated activated sludge and 500 p.p.m. substrates.

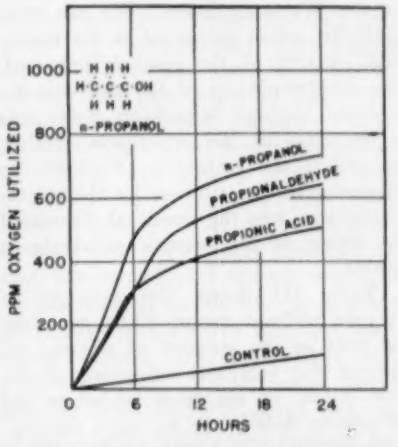

FIGURE 4.—Oxygen utilization of *n*-propanol-acclimated activated sludge and 500 p.p.m. substrates.

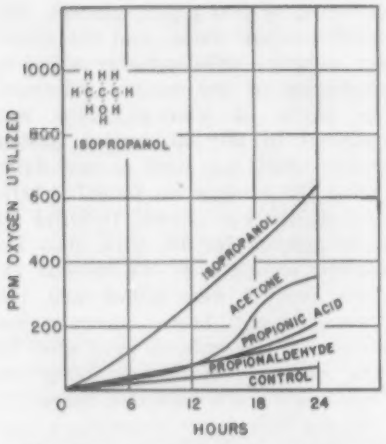

FIGURE 5.—Oxygen utilization of isopropanol-acclimated activated sludge and 500 p.p.m. substrates.

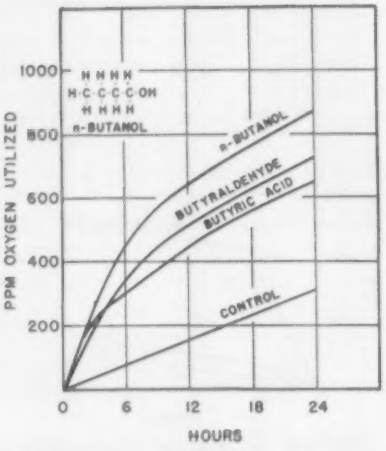

FIGURE 6.—Oxygen utilization of *n*-butanol-acclimated activated sludge and 500 p.p.m. substrates.

organic acid. The alcohols, aldehydes, ketones and organic acids used in this study are listed in Table I.

Results

The suspended solids concentrations contained in the Warburg flasks during the oxidation studies are given in Table II. The solids concentration of the mixed liquor in the aeration units were exactly twice the solids contained in the Warburg flasks. For the most part the solids increased as the molecular weight of the alcohol increased. As the complexity of the molecule increased through branching, there was a decrease in the organisms' ability to utilize the molecule. Part of the decrease in assimilation by the microorganisms was the result of decreased solubility of the organic substrate in water.

Table III shows the quantity of oxygen utilized during 23 hr. aeration, as well as the amount of oxygen required for complete oxidation of the 500 p.p.m. of substrate added to the Warburg flasks. In all cases the corresponding aldehydes indicated a lower percentage of theoretical oxidation than either the acid or the alcohol on which the organisms were acclimated.

The oxidation curves as determined from the Warburg analyses are shown in Figures 2 through 8. The methanol-acclimated sludge quickly oxidized the methanol, reaching equilibrium at 6 hr., but did not metabolize formaldehyde and oxidized formic acid slowly. Ethanol was readily metabolized, as was acetic acid and acetaldehyde.

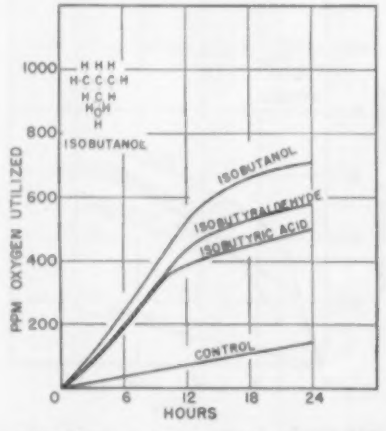

FIGURE 7.—Oxygen utilization of isobutanol-acclimated activated sludge and 500 p.p.m. substrates.

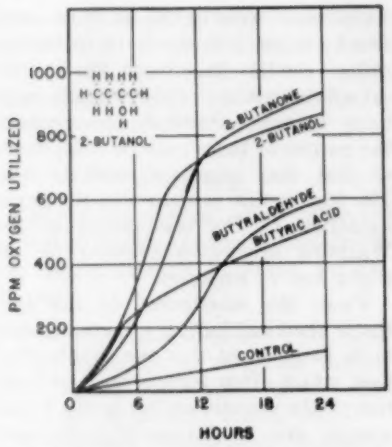

FIGURE 8.—Oxygen utilization of 2-butanol-acclimated activated sludge and 500 p.p.m. substrates.

Normal propanol sludge utilized the corresponding aldehyde and acid by 9 hr. aeration, but iso-propanol was utilized more slowly, not reaching equilibrium even within 24 hr. The iso-propanol sludge did not readily metabolize acetone, propionic acid or propionaldehyde, but showed adaptive tendencies within 24 hr. The butanol sludges gave normal patterns with *n*-butanol, isobutanol and 2-butanol. Tert.-butanol showed negligible oxidation and its curves are not given.

Discussion

Based on the experimental results, the normal alcohols above methanol all followed the pattern of normal oxidation from alcohol to aldehyde to organic acid. The organic acids were in part broken down to carbon dioxide and water to obtain the energy required to convert the remaining acids into cellular materials. From established patterns of bacterial metabolism, acetic acid enters the basic metabolic scheme as "active" acetate in the tricarboxylic acid cycle; propionic acid enters the tricarboxylic acid cycle through pyruvic acid; butyric acid enters the same cycle as "active" acetate. Butyric acid exhibited the property that the higher even carbon acids exhibit; namely, beta-oxidation to yield "active" acetate. The higher acids containing an odd number of carbon atoms are broken down by the same process to yield one molecule of propionic acid and several moles of "active" acetate. Thus in this way, the metabolism of the fatty acids is tied in with the metabolism of the simple alcohols.

The methanol-acclimated activated sludge, while able to utilize methanol, and formic acid to a lesser extent, was unable to utilize formaldehyde. Failure of this sludge to attack formaldehyde indicated the absence of the necessary intermediate enzymes in the organisms metabolizing the methanol. It appeared that the methanol was metabolized by a different oxidation pathway than the other normal alcohols. Little information is available on the bacterial metabolism of these single carbon compounds; none of the information available casts any light on the metabolic pathways for methanol. At present a detailed study is being made to determine more fully the metabolism of the single carbon compounds and their interrelationships.

The iso-alcohols exhibited two patterns of metabolism; isopropanol showed a retarded pattern from the normal alcohols, whereas isobutanol showed the normal pattern. Theoretically, isopropanol would be oxidized to acetone and then to pyruvic acid and the tricarboxylic acid cycle. This did not appear to be the case, since acetone was not readily metabolized. But the isopropanol sludge was able to adapt itself to acetone in a short period and also showed adaptive tendencies toward propionaldehyde and propionic acid. The chemical structure of isobutanol permitted the oxidation pattern to proceed through isobutyraldehyde and isobutyric acid in much the same manner as normal bu-

tanol. The rapid oxidation of isobutanol indicated that the metabolic pathway was relatively simple and was in all probability connected with the tricarboxylic acid cycle. Unfortunately, nothing is known at the present time as to how the isobutyric acid is further broken down to enable it to enter the tricarboxylic acid cycle.

Structurally, 2-butanol is more closely related to isopropanol than is isobutanol. The hydroxyl group on 2-butanol resides on the second carbon, as the name implies. As in the case of isopropanol, isobutanol would be expected to be oxidized to the ketone, 2-butanone, to acetoacetic acid to "active" acetate and then into the tricarboxylic acid cycle. Unlike isopropanol, isobutanol followed the theoretical pathway. This was more clearly evidenced by the fact that butyric acid, although not directly related structurally to 2-butanol, followed the same pathway. On the other hand, butyraldehyde, which is related to butyric acid, showed a definite adaptive lag before being metabolized by the 2-butanol activated sludge. Thus the metabolic pathways of *n*-butanol and 2-butanol, while having separate and distinct initial metabolic pathways, joined and followed the same final pathway into the tricarboxylic acid cycle.

Tertiary-butanol is a structural misfit in the metabolic patterns of the microorganisms. The structure is such that the alcoholic group cannot be further oxidized without splitting the molecule. Rupture of the molecule in such a manner is quite uncommon in bacterial metabolism and can be accomplished only very slowly. The method of operation with one-third wasting did not permit proper build-up of an acclimated sludge.

One of the major problems encountered was that of solubility of the compounds studied. All of the alcohols, aldehydes and ketones studied were volatile and a certain amount of the compounds were stripped from solution by aeration in the activated sludge units. On the other hand, the biological solids and the rapid enzymic reactions quickly adsorbed and changed the nature of these volatile compounds so that they were not entirely lost. The high solids content and the rapid oxidation of the compounds in the Warburg apparatus attested to the slight loss of organics.

From the standpoint of the synthetic chemical industry there appears to be little doubt that the simple alcohols, which often form a large proportion of the organic matter in the liquid wastes, can be successfully disposed of by biological treatment. For the most part a system acclimated to the alcohols can readily handle the oxidized organics related to the alcohols. The ease in metabolism appears to be a factor of the ease in which the organic compound can enter into the common pathway of aerobic metabolism, the tricarboxylic acid cycle. As long as the compound can be broken down to fit into the common metabolic pattern, the metabolism is rapid; but once the structure causes a deviation from the common pattern, it is broken down very slowly and with much difficulty on the part of the microorganisms. The compounds studied which had difficulty entering this cycle were isopropanol and tert.-butanol. While methanol was readily metabolized, it was not metabolized by the pathway of normal chemical oxidation. Addition of formaldehyde to a methanol-acclimated activated sludge system would result in only slight removals until an acclimated seed was built up to handle these materials separately.

The understanding of the common metabolic pathways and their points of entry are two keys to the proper development of biological industrial waste disposal systems. Use of this information can permit the engineer to make a reasonable estimate on

treatability of the synthetic chemicals contained in the liquid wastes being studied, as well as to determine the type of treatment required and possible pilot-plant requirements.

Summary

Laboratory studies using batch-fed activated sludge systems acclimated to the simple alcohols indicated the following:

1. Methanol-acclimated activated sludge metabolized methanol rapidly and formic acid more slowly, but failed to metabolize formaldehyde.

2. Ethanol, *n*-propanol, *n*-butanol and isobutanol all readily metabolized with an oxidation pattern through the corresponding aldehyde and acid to the tricarboxylic acid cycle.

3. Isopropanol was metabolized slowly and did not appear to undergo oxidation to acetone as the first step of oxidation.

4. 2-Butanol was metabolized rapidly through the oxidation pattern to 2-butanone to acetoacetic acid to "active" acetate and the tricarboxylic acid cycle.

5. Tert.-butanol was not metabolized to any appreciable extent.

6. Metabolism of the synthetic organic compounds by the organisms contained in activated sludge appeared to be a function of the chemical structure of the compound and the ease with which it fitted into the general metabolic patterns of the microorganisms.

Acknowledgment

This work was supported in part by a research grant from the National Microbiological Institute, National Institutes of Health, U. S. Public Health Service.

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See front inside cover of this issue for details.

THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

EFFICIENCY IN WORK ASSIGNMENT

BY LLOYD V. OWENS

Superintendent, Division of Sewage Treatment, Public Works Department, Eau Claire, Wis.

The word "efficiency" has many definitions. To an engineer, efficiency is the ratio of effect produced to the energy expended. Accordingly then, the efficiency of an organization might well be the ratio of effort expended by supervision to the results produced by the employees.

One of the greatest single factors detrimental to efficiency is inadequate work assignment. This covers much of the responsibilities of supervision. Work assignments might be broken down for comparative purposes into:

1. Daily oral assignments.
2. Daily written assignments.
3. Project assignments.

Means of Assignment

The daily oral assignment of work is perhaps the most widely used, but it also can be the most inefficient unless close supervision is exercised. In the first place, misinterpretation of instructions by employees may result in extensive loss of time and material. Secondly, the supervisor has only his memory to record work assigned on any given day. It is essential that the supervisor be available to distribute the work each day. Therefore, the supervisor is tied down when he relies entirely on oral assignments.

The daily written instructions, although probably less used, can be far more efficient than oral instructions. This method of work assignment permits greater flexibility in work planning, because it gives the supervisor a record of how much time has been spent on a job. Accordingly, a reasonably accurate estimate of the time required to complete the job is possible.

The written method of work assignment has been adapted to operations at the Eau Claire (Wis.) sewage treatment plant. The work plan consists of a mimeographed, 8½-in. by 11-in. form, on which work is assigned for one 24-hr. period (Figure 1). The routine work list for each shift is on file at the plant, and each shift is automatically responsible for it. The work plan is for assignment of work which is in addition to routine duties. There should be a definite distinction between the two. For example, the electric meters are read at midnight by the operators of the 11 PM–7 AM shift; hence, this is routine work and need not be assigned on the work plan.

An assignment board mounted on a wall in the administration building accommodates assignments for four days. This allows the superintendent to post work to cover week-ends or periods when he may be absent from the plant.

One of the most important functions of the work layout plan is to schedule regular maintenance operations. A master maintenance chart is prepared on a calendar form a year in advance. From this chart all maintenance functions are transferred to the daily work

SEWAGE TREATMENT PLANT
Eau Claire, Wisconsin

Date June 15, 1968

WORK LAY-OUT PLAN

The work to be accomplished by each shift listed hereon, is in addition to the routine duties of each shift. Only work of an emergency nature will have priority over routine shift work and the special work listed on this form. All concerned will list plausible reason if their work assignment is not completed.

WORK ASSIGNMENT Shift - 11 PM - 7 AM Operator Bill Jones

1. Pump sludge to digester No. 1.
2. Clean air breathers on engine and two air compressors.
3. Drain water traps on gas lines.

The work listed for my shift (has) (has not) been completed. _____ OPERATOR'S SIGNATURE

WORK ASSIGNMENT Shift - 7 AM - 3 PM OPERATOR Fred Smith and Jim Brown

1. Pump sludge to digester No. 2.
2. Repack No. 3 sewage pump.
3. Grease all equipment at plant and booster stations.
4. Clean exterior of No. 1 and 2 sewage pumps.
5. Paint No. 1 sewage pump (gray).

The work listed for my shift (has) (has not) been completed. _____ OPERATOR'S SIGNATURE

WORK ASSIGNMENT Shift - 3 PM - 11 PM Operator Joe Johnson

1. Pump sludge to digester No. 1.
2. Change oil in engine, clean oil filter.
3. Check all fire extinguishers and brackets. Weigh CO_2 extinguisher and record here ____ lb.

The work listed for my shift (has) (has not) been completed. _____ OPERATOR'S SIGNATURE

WORK ASSIGNMENT 8 AM - 4 PM Chemist John Green

1. Run complete analyses on raw and digested sludge samples.
2. Complete analyses on water sample from Board of Health.
3. Begin river survey, vicinity of plant outfall.
4. Continue chlorine demand tests.

The work listed for my shift (has) (has not) been completed. _____ CHEMIST

Off-duty operators:
Bob White
Sam Black

FIGURE 1.—Typical daily work layout plan.

assignment sheet. This system assures that all maintenance is performed in proper sequence and that nothing is overlooked. It also gives a permanent record of when work was done and who did it.

Since the inception of this plan in November 1953, results have been more than satisfactory. It is possible to plan the work better and distribute it more evenly, accomplishing much more than previously with the same number of men. There is no confusion at shift changes and, even if the superintendent is not present, the work is all assigned with every man knowing exactly what is expected of him.

Project assignments may be either oral or written. In any event, this type of work assignment may cover a period of one day to several weeks, depending on the amount of work required to complete the project. As an example, the project might consist of painting all grease and oil points on plant equipment. The project is assigned to an operator, who is responsible for seeing that it is completed. One operator working on such a project will usually produce better results than assigning a certain amount of work to each of several different shift operators. There is always the possibility of a worker assuming that another did certain work, when in reality the item was actually overlooked by both.

A psychological factor not to be overlooked is that project assignment places the responsibility for the entire project on one individual. He knows then that any careless or incorrect work can be attributed only to him. Therefore, if he is at all interested in his job, he will take pains to produce work of which he will be proud. He no doubt will accomplish the work faster than if the work had been assigned piecemeal on the daily basis. This type of work assignment has been used whenever possible, and has been found to work well, particularly with certain individuals. In these cases the same project is listed each day for the same individual until it is completed. However, the progress must be indicated on the daily work plan.

Supervision Suggestions

Some suggestions in basic supervision of employees are:

1. Always plan the work well in advance. Let the employees know what is expected of them and accept their suggestions with an open mind. If employee ideas are used, acknowledge them and let the employees know that their interest in the work is appreciated.

2. Assign work on the basis of skills. For example, if a man is particularly good at electrical repair work it is more efficient to use him for that type of work than one who may fumble around for hours to accomplish a half-hour job.

3. Be fair in work distribution. Don't give all the easy jobs to one individual and all the difficult and disagreeable jobs to another. Favoritism can destroy morale more rapidly than any other single element.

4. Make sure all supplies and materials are ready before assigning a job.

5. Be consistent in all policies regarding supervision. Don't be a tyrant one day and a "Milquetoast" the next.

6. Arrogance has no place in supervision and the only reward will be contempt instead of respect. Treat the men as you would have them treat you if the situation were reversed.

7. Be considerate of the employees. Keep "rainy day jobs" in reserve for such a purpose. There is no excuse for any supervisor to work his men out of doors in inclement weather, except in emergencies.

8. Be sympathetic toward the employees. If an individual is not feeling well, lighten his work load.

9. Use common sense in work assignments; do not expect the impossible. Unreasonableness generally indicates lack of maturity or intelligence.

Supervising a group of men as it should be done requires every minute and more of the supervisor's time. People who have never worked in a supervisory capacity may think that it is easy. Unfortunately, responsibility is not a tangible thing. An individual employee may be familiar with only a small portion of the over-all responsibility. When he leaves his job for the day his "work-a-day" cares and worries are left behind. The supervisor, on the other hand, takes his responsibility with him at all times, whether he is at home, at church, fishing, or vacationing. But there is much satisfaction in setting a goal and attaining it; in knowing that the amount of effort put forth as a supervisor has produced the desired results.

INITIAL OPERATING PROBLEMS AT SALISBURY, NORTH CAROLINA *

By John N. Lesslie

Chemist and Superintendent, Sewage Treatment Plant, Salisbury, N. C.

New waste treatment plants invariably have initial operating problems, but the one at Salisbury, N. C., was literally a stinker. Sulfur dye waste from the local cotton mill, in combination with the domestic sewage, produced a vexing composite. The highly colored waste has a B.O.D. ranging from 350 to 600 p.p.m., is almost septic, and has a chlorine demand in excess of 200 p.p.m.

The problem was attacked jointly by the City of Salisbury, Cone Mills, and the North Carolina State Board of Health. Financing of the treatment plant was also a joint venture. Cone Mills assumed a part of the capital costs. In addition, all chemicals used in the treatment of the dye wastes, except chlorine, are paid for by the mill.

Plant Units

The character of the waste to be handled requires extensive and rather expensive treatment. Therefore, the treatment plant was designed as a large-scale pilot plant capable of handling 2 m.g.d. of industrial waste and sewage. Provision is made for chemical treatment at various locations in the flow plan. Sufficient flexibility is incorporated to aid in meeting unforeseen problems.

Treatment units provide for grit removal with air, followed by a mechanically cleaned bar-screen and screenings grinder. A flash mixer and a 70-ft. diameter concentric aerator and settling unit † (Figure 1) permits chemical treatment of the strong dye wastes. Air is used as the flocculating mechanism. Following, is a second mixing chamber using air. A high-rate biofilter with pumping facilities for three rates of application provides the secondary treatment. An existing clarifier, part of the old treatment plant, is utilized for secondary clarification. Chlorinating facilities and contact chamber complete the treatment units.

Sludge digestion is handled in two

* Presented at 1954 Annual Meeting, North Carolina Sewage and Industrial Wastes Assn.; Asheville, N. C.; Nov. 8–10, 1954.

† "Oxidator" unit, manufactured by Process Engineers, Inc.

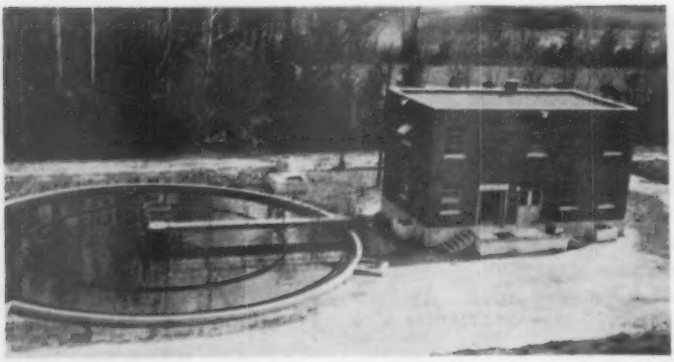


FIGURE 1.—Pretreatment and clarifier unit (left) and chemical control building.

40-ft. existing digesters. Although additional digester capacity was not included in the initial construction, it is planned for the future.

Two flow-controlled chemical feeders were installed so that chemicals can be applied at one or both mixing chambers. In addition, two recording pH meters are included for process control.

The waste treatment facilities were initially placed in operation during the latter part of May 1954. The ensuing five months of operation have been spent in working out the "bugs." Although considerable experimenting has been tried, there has been little opportunity to search for the optimum. However, the experiences gained from the operation of this plant should be of value in future expansion of the facilities, and it is hoped that they will be of use in designing other treatment plants faced with a similar problem.

Mechanical Problems

The only serious mechanical problem developed soon after starting plant operation. Material deposited in the grit unit is removed by air through a 3-in. pipe. The manufacturers of the unit recommended that the screen be placed ahead of it. Because the screen involved moving parts subject to wear from grit and was the more expensive of the two, the grit unit was placed in front of the screening equipment. As a result, the first large rag to hit the 3-in. pipe stopped it up.

A satisfactory solution was obtained by placing a 1½-in. hand-raked screen across the influent of the grit removal unit. This screen does not require much raking, and has permitted continuous operation.

Treatment Problems

Many attempts had been made in prior years to treat the sulfur dye waste at Salisbury by coagulation with various chemicals. One of the first tried was alum. No attention was given to pH control, with the sole criterion being the settleability of the floc. The pH ranged between 5.8 and 6.4, the optimum normally expected with alum. Good results were obtained as far as clarification and color removal were concerned, but the odor of the hydrogen sulfide generated was so intense that alum was immediately dropped from the list.

Investigation of treatment possibilities showed that, with alum, if the pH was controlled at 7.0, good clarification and color removal could be obtained with a minimum of hydrogen sulfide generation. As a result, alum was chosen as the first chemical for use in the new plant.

The treatment plant was operated

for a few weeks without using alum in order to start a growth on the filter. Then alum was applied through the primary mixing chamber with flocculation taking place in the central portion of the primary unit, where 200 c.f.m. of air was introduced. The effluent went to the filter at the highest rate obtainable, approximately 40 m.g.a.d., or a 7:1 ratio.

From the start, considerable hydrogen sulfide was blown into the atmosphere from the primary unit, even though the pH was maintained at 7.0. This hydrogen sulfide was already present because, even without alum, it could be detected when strong sulfur dye waste was coming into the plant.

Due to the fact that it took the plant neighbors nearly a month to track down the source of odors, there was some time in which to gather data on the possibilities of alum coagulation.

At this time the digesters were almost empty, and supernatant was not being returned to the plant. Results were excellent, even though the filter was only partially seeded. Over-all B.O.D. reduction approached 90 per cent, with a final B.O.D. of less than 40 p.p.m. (Table I). The effluent was only slightly stained with color.

The chlorine demand was reduced from 200 p.p.m. to less than 15 p.p.m. This made post-chlorination feasible.

The required alum dose averaged 120 p.p.m. at a cost of approximately $23 per m.g. and represents the cost per m.g. of composite sulfur dye and sewage waste. This dosage was used only during the time that sulfur dye was coming into the plant. During this period good results could be obtained on domestic sewage without chemical treatment, and fair results could be obtained on vat dyes without chemicals.

About this time the neighbors found the source of the odors. Odors from the plant had traveled as much as 4 mi. at night. This night travel of odors became a pattern. In the daytime almost anything could be done, but at night the slightest odor brought a storm of protest. Many trips were made at two and three o'clock in the morning to investigate complaints.

Efforts to use alum were halted, but aeration was continued. Still the complaints came in. Aeration was temporarily stopped and alum treatment resumed. This reduced the complaints to those living within ½ mi. of the plant. Odors were much less intense, but the slightest whiff of sewage brought protests and threats.

Complaints were received at night even when neither alum nor air was being used. These odors were caused in part by the high retention time at night, resulting from low flows. Septic odors were mixed with the sulfide odors. In addition, there was a slight odor from the grit chamber when the air was on.

Without pretreatment, results on the sulfur dye waste composite fell off quite a bit. Good results were obtained on domestic sewage, but the filter alone could not handle the heavy load of dye waste.

In an effort to stabilize the sulfides, the pH of the sewage was raised to

TABLE I.—Initial Results Using Alum Coagulation

Sample	Total Solids		Suspended Solids		B.O.D.	
	(p.p.m.)	Reduction (%)	(p.p.m.)	Reduction (%)	(p.p.m.)	Reduction (%)
Raw sewage	2,160	—	280	—	360	—
Clarifier effl.	1,690	—	98	65	168	53
Final effl.	1,582	27	40	86	36	90

FIGURE 2.—Heart of the Salisbury, N. C., waste treatment plant.

8.5–9.0 and aeration was resumed. This unit functions quite well on everything except the stronger sulfur dye concentrations. High suspended solids are maintained in the pretreatment unit, and these solids have an adsorptive effect on colloids and color. It was hoped to revive this action by raising the pH with lime. As a result, odors were reduced but were still quite strong when receiving sulfur dye.

By this time the digesters were full and it became necessary to return supernatant to the plant. One of the digesters gave no trouble, but the other had a terrible odor that added greatly to the over-all odor problem.

Use of Lime

The odor accumulation was too much, and thought was given to raising the pH in order to lessen the odor problem. However, there was the question of whether or not the filter could stand the pH of 10.5 or higher required for lime coagulation of the dye waste.

Lime was tried and the filter did not slough off. There was, however, a definite reduction of activity in the filter and efficiency decreased. The ability of the filter (Figure 2) to tolerate the high pH was probably due to the fact that for some weeks previous a pH of 8.5 or higher had been maintained using lime.

Lime coagulation at pH 10.5 solved the odor problem from the pretreatment unit, and the first period of freedom from complaints was enjoyed. Treatment was not satisfactory and the cost was entirely too high for the results obtained. The dosage required 240 p.p.m. at a cost of $20 per m.g. To protect the filter, it was necessary to maintain this treatment around the clock. Alum, however, could be used intermittently at a considerable saving in total cost.

Previous efforts to use lime in the old plant had clearly shown that the best and most economical results were obtained when a large portion of the lime was applied to the sulfur dye waste leaving the holding tank at the mill.

Although this waste could not be coagulated with lime, as soon as it was diluted with a small amount of mill village sewage, a beautiful floc could be obtained. Greater dilution with sewage before treatment reduced the coagulating efficiency. The cost and lower efficiency of lime coagulation resulted in continuing the search for a method that would permit resuming the use of alum. Ferric sulfate coagulation at pH 8.0 was tried.

Odors were reduced, but poor color removal was obtained.

The use of a small amount of ferrous sulfate was suggested to stabilize the sulfides, thus permitting alum treatment with aeration. This helped, but small amounts of hydrogen sulfide were still discharged to the atmosphere, along with a slight odor from the grit chamber.

The next effort was to feed sodium nitrate into the incoming sewage as a source of oxygen. Since the D.O. of the sewage was zero, this sounded like a good idea. A dosage of 20 p.p.m. was applied. Here again there was an apparent reduction in odors, but the level was still high enough to bring complaints from close neighbors.

The chief benefit derived from using sodium nitrate was a reduction in septic odors at night, when the flow at times dropped to 0.5 m.g.d. This increase in detention permitted the sewage to become septic at summer temperatures, and resulted in considerable odor, especially when aeration was used. According to many authorities, the sodium nitrate served as a source of oxygen for the bacterial population, and helped maintain the oxygen-reduction potential high enough to lessen the activity of anaerobic microorganisms.

A Solution

No quantitative studies were made during these attempts to handle the problem. The sole criterion was whether or not the telephone rang at 2:00 AM.

The search went on. Various combinations of all chemicals on hand were tried—with reason and without. Then the Director of Public Works heard that an emulsifiable chlorobenzene * was being used with success at Newton, N. C. Laboratory tests of a 1-gal. sample on putrid sludge showed that the material would kill or mask odors. Accordingly, a drum was ordered.

Immediately upon receipt of the chemical, treatment was started. After some juggling to determine an effective dose, a dosage of 5 g.p.d., or approximately 4 p.p.m., was applied. Five gallons were placed in a 50-gal. drum, and the drum filled with water. The dosage was controlled with a stopcock set to feed the 50 gal. in 24 hr. Application was made ahead of the grit chamber.

Results were truly dramatic. Odors from the grit chamber disappeared, and the deposited grit was no longer a nuisance to handle. This reduction in odor held regardless of the type of sewage or its septicity. The only detectable odor was a slight one from the chemical. Results were equally good in the pretreatment unit; therefore, full aeration was resumed. This opened up an entirely new vista, and alum treatment of the sulfur dye waste was again tried.

Return to Alum

At first the pH was controlled at 7.0, and odor-free operation was enjoyed. Treatment efficiencies, although good, were not as good as could be obtained if the alum were applied for best coagulation rather than for minimum hydrogen sulfide generation. Accordingly, the alum dosage was increased to give a coagulating pH of 6.4. At this pH the effluent of the clarifier showed no color, but was slightly turbid. A slight color stain was picked up going through the filter, but the turbidity was removed.

The quality of the effluent was not as good as that obtained when the plant was first placed in operation. This may have been caused by returning digester supernatant to the clarifier at the same rate that sludge is pumped. Also, the treatment plant has been operated under all conditions of color and B.O.D. removal, resulting in a general fouling of the

* Orthosolv, manufactured by Solvay Process Div., Allied Chemical and Dye Corp.

TABLE II.—Results Using Odor Control, and Alum for Coagulation at pH 6.4

Sample	Total Solids		Suspended Solids		B.O.D.		Chlorine Demand	
	(p.p.m.)	Reduction (%)	(p.p.m.)	Reduction (%)	(p.p.m.)	Reduction (%)	(p.p.m.)	Reduction (%)
Raw sewage	2,734	—	300	—	420	—	220	—
Clarifier effl.	1,635	40	70	77	192	54	—	—
Final effl.	1,586	42	57	81	96	77	16	93

filter and secondary clarifier. It is hoped that when the clarifier and filter are flushed out the effluent will show material improvement.

Under previous conditions aeration would have driven tremendous quantities of hydrogen sulfide into the air at this low pH. Using the odor masking chemical, a slight bitter-sweet odor was all that could be detected, and even at night no complaints were received.

It is said that the exception proves the rule. One night the chemical feed valve stopped up, and in a short time complaints were received from as far as 1½ mi. from the plant. The complainants were requested to call back if the odors persisted for more than an hour. Chemical feeding was resumed and no calls were received.

Treatment of sulfur dye wastes at present consists of deodorization, coagulation with approximately 140 p.p.m. of alum, flocculation with air, settling, filtration at an applied rate of 28 m.g.a.d., and secondary clarification. Chlorination facilities are available, but are not used at present.

The following cost of treatment applies only for the period that sulfur dye waste is received at the treatment plant:

Item	Cost, per m.g.
Alum	$26.00
Deodorizer	7.00
Pumping	7.00
Total	$40.00

On a weekly basis the total cost is much less.

At present, alum is not used on vat dye waste or on domestic sewage, and the rate of application to the filter is 40 m.g.a.d. Typical results now being obtained are given in Table III. The effluent from the filter contains dissolved oxygen at all times, ranging between 1.5 and 4.0 p.p.m.

In spite of the generous application of air, there has never been any dissolved oxygen in the influent to the filter. Apparently this should be expected. One trouble may be a build-up of suspended solids in the pretreatment unit that is difficult to control. Suspended solids in the unit

TABLE III.—Results When Treating Vat Dye Wastes or Domestic Sewage

Sample		Total Solids		Suspended Solids		B.O.D.	
		(p.p.m.)	Reduction (%)	(p.p.m.)	Reduction (%)	(p.p.m.)	Reduction (%)
Vat dye wastes	Raw	1,075	—	178	—	276	—
	Final effl.	750	30	52	71	96	65
Domestic sewage	Raw	1,064	—	154	—	240	—
	Final effl.	773	27	48	69	60	75

average 5,000 p.p.m. when 200 c.f.m. of air is used. Due to sludge handling limitations, there is a vicious circle as far as solids removal is concerned. Increased pumping results in increased supernatant return. This supernatant is often quite high in suspended solids and is always high in oxygen demand. A small vacuum filter could be used to take up the slack in the sludge load from the primary clarifier. When the digesters failed to yield a good supernatant, sludge removal could be continued without detriment to the plant effluent.

Another current problem is sludge bulking in the pretreatment unit. It is not known whether this is caused by the high suspended solids carried, or a lack of linear distance for settling. A combination of the two is probably responsible. The floc settles in 5 min. in a quiescent state. Reducing the air minimizes, but does not eliminate, this bulking. Additional sludge handling equipment will definitely help, once a place is provided to receive the sludge.

Sludge Digestion

The two existing digesters were not functioning when the new facilities were placed in operation. During the seven years since the last cleaning sand had filled one-fourth the volume of the digesters. One digester was cleaned by discharging the sand and sludge to the drying beds. All of the drying beds were not used, the empty ones being filled with sludge from the second digester. The remainder of the sludge was pumped into the cleaned unit. After cleaning the second digester, the stored sludge was equalized between the two as seed material.

Shortly before the treatment plant was placed in operation consideration was given to the use of cultures of preserved bacteria to aid the activation of the digesters. Knowing that there were some differences of opinion concerning the value of these materials, it was decided that an ideal setup existed for a test. If there was any value in this material it would be as seed for dead or sick digesters. With this thought in mind, a "no-result-no-pay" trial was carried out.

The No. 1 digester was chosen for the test, with the No. 2 unit held as a control without seeding. The pumping program was divided equally between the two digesters, changing every one or two days. The digesters can be heated, but during this test the boiler was not working. There is no provision for recirculating or agitating the sludge.

An initial dose of 10 lb.* was applied to the No. 1 digester on May 29, 1954, followed by quantities of 5 and 10 lb. at 4- to 7-day intervals. The pH of both digesters was 5.6. Gas development and pH changes in the two digesters were as follows:

Date (1954)	Gas Production		pH	
	Dig. 1	Dig. 2	Dig. 1	Dig. 2
June 5	Slight	None	5.6	5.6
June 9	Increased	None	6.0	5.6
June 16	Fairly low	None	5.8	5.4
July 2	Rising	Trace[1]	6.2	5.8
July 15	Good	Slight[1]	6.6	6.2
July 20	Full	Moderate[1]	6.8	6.4
Aug. 6	Full	Almost full[1]	6.8	6.8

[1] Supernatant had extremely foul odor.

Liming of both digesters was started on June 23. The lime was applied to the sludge pumped to the digesters at the rate of 500 lb. every other day for 7 days. Another 100 lb. of culture was received, and treatment was continued with 10- and 15-lb. doses at 4- to 7-day intervals.

Because of the extremely foul odors, use of digester No. 2 was suspended from July 20 to July 30, with unit No. 1 carrying the entire load.

The first sludge was drawn to the drying beds on August 17.

The results (Table IV) show pro-

* Bionetic II—Petrodec, furnished by Reliance Chemicals Corp., Houston, Tex.

TABLE IV.—Comparison of Digested Sludge from Digesters No. 1 and No. 2

Date (1954)	Digester No. 1		Digester No. 2	
	% Solids	% Volatile	% Solids	% Volatile
Aug. 17	4.4	54	—	—
26	3.7	57	3.6	55
31	12.8	49.8	13.1	44.6
Sept. 3	—	—	9.3	46.6
7	8.2	45.9	—	—
22	7.3	41.9	7.0	40.5

gressive improvement in both digesters. All sludge drawn has been free from offensive odor and has drained well. The odor from the No. 2 digester gradually decreased and both units are working efficiently.

Benefits derived from seeding included a saving of more than 30 days in arriving at full gas production and an apparent elimination of the period of odorous fermentation that so often accompanies the starting of a new digester. For these reasons the bill for the cultures was paid.

It is believed that there is possibly a place for artificial seeding with materials such as preserved cultures, in starting up new digesters or in the rejuvenation of sick digesters. However, once a digester is functioning, and as long as nothing happens to upset its activity, adding artificial seed would seem to be like pouring a cup of water in the ocean.

The only objection to the method of seeding is the cost. For the two hundred pounds used in this project, the cost would have been approximately $600. This seems high, but that is a matter for the potential user to decide.

At present the treatment facilities are capable of producing an effluent to meet almost any reasonable requirement.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"The biggest mistake is the fear that you will make one."—*Anon.*

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, 4435 Wisconsin Ave., N.W., Washington 16, D. C.

1953 Annual Report of the Muskegon Heights, Mich., Sewage Treatment Plant *

By C. F. Harrison, *Superintendent*

Considerable construction work was completed during the year. A permanent chlorine building and chlorine contact chamber replaced a temporary installation 10 years old. In order to chlorinate all the plant effluent, a lift station was constructed to pump the effluent from the contact rock filter and the sand filters to the chlorine contact chamber. After 22 years of service the bar screen was replaced with a

* For last previous extract see This Journal, **24**, 1, 102 (Jan., 1952).

comminutor. In addition, new grit removal equipment was placed in operation. Final protection for the plant grounds was completed when a fence and gates were constructed along the south side of the site.

A fresh coat of paint was applied to the walls, ceiling, and floor of the pipe gallery and tool house. Piping, valves, and floor of the chlorine building also were painted. A new roof was installed on the contact filter building and all woodwork was painted inside and out.

Equipment in the secondary settling tanks was inspected and found to be in good condition. Both primary clarifiers also were inspected and found satisfactory. Bearings were replaced in one aeration gear unit and a new drive chain installed on the other. Aeration tanks were very inefficient due to insufficient air capacity coupled with a short detention period. Air available was less than 0.5 cu. ft. per gallon of sewage.

Some difficulty was experienced with clogging of the organic return pump on the new grit removal equipment. Correction was made by extending the organic return elbow by 3 in. through the addition of a sheetmetal sleeve. This increased the submergence of the organic pump propeller.

The sand filters were used for 5 months and the contact filters for 10 months. All sewage was treated in the activated sludge units prior to diversion either to the filters or the receiving stream. Chlorination of the plant effluent took place during July, August and September. Over-all treatment efficiency averaged 81.5 per cent reduction in B.O.D.

A summary of operating data for 1953 is given in Table I.

TABLE I.—Summary of 1953 Operation Data, Muskegon Heights, Mich., Sewage Treatment Plant

Item	Average
Estimated population served	20,000
Rainfall (in.)	25.28
Sewage flow (m.g.d.)	1.63
Screenings (cu. ft./m.g.)	1.5
Grit (cu. ft./m.g.)	1.6
Organic content (%)	43.0
B.O.D., 5-day (p.p.m.):	
Raw sewage	230
Primary effluent	170
Act. sludge effluent	51
Rock filter effluent	35
Sand filter effluent	8
Final effluent	42.0
Removal (%)	81.5
Suspended solids (p.p.m.):	
Raw sewage	242
Primary effluent	134
Act. sludge effluent	67
Rock filter effluent	62
Sand filter effluent	8
Final effluent	57
Removal (%)	76.3
Settleable solids (ml./l.):	
Raw sewage	7.2
Primary effluent	.8
Dissolved oxygen (p.p.m.):	
Rock filter effluent	3.6
Sand filter effluent	5.7
Upstream	10.9
Downstream	8.9

Item	Average
Raw sludge data:	
Total (gal./m.g.)	4,937
Solids (%)	4.3
Volatile solids (%)	77.4
pH	6.3
Digested sludge:	
G.p.d.	2,271
Solids (%)	6.16
Volatile solids (%)	55.0
pH	7.0
Gas production:	
Dig. temperature (°F.)	87.5
Dig. No. 1 (cu. ft./day)	12,292
Dig. No. 2 (cu. ft./day)	10,313
Waste burner (cu. ft./day)	10,083
Total (cu. ft./lb. vol. sol. added)	10.09
Total (cu. ft./lb. vol. sol. dig.)	12.15
Activated sludge:	
Aeration period (hr.)	5.4
Sludge return (%)	22.1
Wasted sludge (g.p.d.)	45,000
Effluent to stream (%)	68.8
Effluent to filters (%)	31.2
Sludge index	70
Air use (cu. ft./gal.)	.47
Operation costs ($/m.g.):	
Sewer system	46.73
Treatment plant	63.05
Overhead	15.87
Total	125.65

Annual Report of the Toledo, Ohio, Sewage Treatment Plant for the Year 1953 *

By A. H. Niles, *Commissioner, Division of Sewage Disposal*

The 1953 sewage flow of 41.1 m.g.d. was the lowest since 1946. This is accounted for by the lowest precipitation in almost 20 years, and the second record dry year in succession. The precipitation for the years 1952 and 1953 totaled only slightly above that for 1950 alone, which was 47.84 in. In that year the sewage flow averaged 54.3 m.g.d.

More significant than volume is the amount of suspended solids and 5-day B.O.D. of the raw sewage received at the treatment works. In 1950, 26,378,000 lb. of suspended solids were received and in 1953 the amount was 26,681,000. A considerable amount of silt was contained in the 1950 solids due to the higher sewage flow and more infiltration. The strength of the sewage in 1950 average 169 p.p.m. and in 1953 it was 243 p.p.m.

A staff of 64 employees maintained the operations of the division in first-class condition. The division of sewage disposal was responsible for the pumping stations and treatment facilities. Chlorination of the plant effluent was required as usual during the summer for bathing beach protection. The major plant improvement was to remove the cork cushion on which the 4-cylinder gas engine was mounted. After 17 years of service the cork was so badly compressed that it provided very little cushioning effect. The gas engines, now in their eighteenth year of operation, are in satisfactory condition, although maintenance cost has increased.

Industrial Wastes

Operations of the Rossford Plant, Amino Products Division, International Minerals and Chemical Co., were at a high level. The stored end liquor from the Steffens process in the production of monosodium glutinate was discharged to the sewers starting in December, when the company was unable to sell the liquor. As a result, the B.O.D. of the plant effluent was often almost as high as the raw sewage, because the the solubility and high strength of this waste.

Tol-e-Gro

Every pound of Tol-e-Gro that could be produced has been sold. In recent years the demand has depleted the stockpile by early spring. The regular selling price of approximately $14 per ton was maintained throughout the year. Production tonnage was somewhat less than the previous year, probably due to fewer hours of sunshine. Maintenance of the sludge drying greenhouses continued to be expensive. The drying of sludge and its preparation and marketing should be studied with regard to present and future conditions.

The processing cost per ton has increased from $4.06 in 1945 to $5.68 in 1953. This does not include general overhead and fixed charges, or the maintenance cost on the sludge beds and greenhouses.

Revenue

The sewer service charges, placed in effect the last quarter of 1952, have averaged $60,100 per month. These charges are based on 25 per cent of the water bill, but do not provide sufficient funds to finance the first phase of the contemplated expansion program. Revenue bonds for this work have been proposed.

A summary of 1953 operating data is given in Table II.

* For last previous extract see This Journal, **25**, 12, 1465 (Dec., 1953).

TABLE II.—Summary of Operation of the Toledo (Ohio) Sewage Treatment Plant for 1953

Item	Average
Rainfall (in.)	22.95
Design flow (m.g.d.):	
Mean, dry weather	80.0
Max., dry weather	140.0
Max., storm	170
Raw sewage flow (m.g.d.):	
Minimum	25.76
Maximum	70.27
Average	41.10
Screenings (cu. yd./mo.)	204
Grit removed (cu. yd./mo.)	55
Suspended solids (p.p.m.):	
Raw sewage	214
Plant effluent	108
Per cent removal	49.3
B.O.D. (p.p.m.):	
Raw sewage	243
Plant effluent	178
Per cent removal	23.3
Digester gas (mil. cu. ft.):	
Total produced	101.83
Utilized	78.40
Wasted	23.43
Volatile solids (%):	
Raw sludge	68.6
Digested sludge	45.2
Digested sludge (cu. yd.):	
To marsh	26,630
To drying beds	8,955
Dry sludge pulverized for fertilizer (tons)	878.3
Fertilizer sold (tons)	916.3*
Total sales ($)	12,849.33
Pumping station costs ($/m.g.):	
Bay View	6.93
East Side	21.01
Sewage works cost ($/m.g.)	11.50
Division cost ($/m.g.)	20.50
Gas engine economy ($):	
Pumping cost if power purchased	22,766.78
Actual pumping cost	11,430.58
Gas engine saving	11,336.20

* Includes sludge carried over from 1952.

First Annual Report of the Port Washington, New York, Sewage Treatment Plant for the Year Ending June 30, 1953

By William C. Hamm, *Superintendent*

The new Port Washington, N. Y. trickling filter treatment plant completely replaces an existing facility constructed in 1916 and enlarged in 1927. Part of the old structure was converted into a pumping station handling 45 per cent of the total sewage flow. The new treatment facility was placed in operation in April 1952.

Plant Design

Duplicate treatment units have been designed to serve a population of 25,000 at 3 m.g.d. Provision has been made for expanding the facilities by 1.5 to 3.0 m.g.d.

An aer-degritter type grit remover and comminutor provide the first step in treatment. The primary clarifiers each have a 2-hr. detention period at 1.5 m.g.d. and are followed by high-capacity trickling filters with a recirculation ratio through the filter and primary clarifier of approximately 1 to 1. Two-hour detention is provided by the secondary clarifier.

Primary and secondary digesters, with a total capacity of 101,390 cu. ft., handle the sludge. Sludge gas is used for hot-water heating of the primary digester and the main building; the excess gas is burned. Digested sludge is discharged to open sand drying beds constructed in the natural sand without underdrains. The dried sludge cake is broken up with a disk harrow and plowed in. With practically unlimited sand area available, it is planned to eventually recover the land to a fertile state for a future park or recreation area.

A Parshall flume and recording equipment, and automatic chlorinators for pre- and post-chlorinating, complete the essential treatment units.

Operation

The first year of operation represented a period of experimenting with the facilities to determine what each unit could do and also to learn the best operating procedures. Representative laboratory tests were made and more complete testing is recommended. The performance tests indicated that operation was at maximum efficiency, with 96 per cent removal of B.O.D. and a suspended solids reduction of 91.5 per cent.

The flow during the year averaged 1.4 m.g.d. from a sewered area of 1,198 acres. The estimated connected population was 11,700 persons, resulting in a per capita contribution of 120 g.p.d.

The average B.O.D. of the raw sewage was 399 p.p.m. compared with a design value of 258 p.p.m. This higher B.O.D. was due to the discharge of wastes from cesspool cleaning companies. These wastes average 10,000 g.p.d. and are high in B.O.D. Additional cost of treatment, particularly chlorine, was more than compensated by the fees collected. Since the cesspool wastes are not at present interfering with operation, the practice of treating the wastes will be continued. At the same time an important public health service is performed.

The effluent averaged 40 p.p.m. prior to chlorination. Since chlorine removes 2 p.p.m. of B.O.D. for each part per million of chlorine demand satisfied, the effluent was chlorinated with 12 p.p.m. of chlorine. This reduced the final effluent to 16 p.p.m. Even with the treatment of a stronger waste than formerly, the chlorine requirements have been reduced 55 lb., or 32 per cent.

Grit removal figured to be only 0.72 cu. ft. per m.g., and was probably due to the removal of considerable grit and sand at the several pumping stations. The grit at the treatment plant had a very low (0.12 per cent) organic content. Disposal was by burial at the sludge bed site.

Excellent sludge digestion and gas production were achieved; ample gas was available for all plant needs. The sludge dried readily on the sand beds and was broken up and plowed in without objectionable odors.

Bacteriological sampling of the chlorinated effluent indicated that a chlorine residual of better than 2 p.p.m. must be maintained to insure a satisfactory bacteria count. Adequate vehicle and equipment storage is needed and the shop space is too limited.

A brief summary of the data obtained during the first year of operation is presented in Table III.

TABLE III.—Summary of Operating Data for the Port Washington, N. Y., Sewage Treatment for the Year Ending June 30, 1953

Item	Average
Population (est.)	11,700
Flow (m.g.d.)	1.4
Grit (cu. ft./mg.)	0.72
Suspended solids (p.p.m.):	
Raw	263
Settled	65
Final	24
Reduction (%)	91.5
B.O.D., 5 day, 20° C. (p.p.m.):	
Raw	399
Settled	103
Final	16
Reduction (%)	96
D.O., effluent (p.p.m.)	6.9
Chlorine:	
Residual (p.p.m.)	2.0
Used (lb./m.g.d.)	117
Sludge, digested:	
Dry solids (%)	6.7
Organic matter (%)	37
Digester gas (cu. ft.):	
Daily production	18,500
Per capita	1.6

HIGH-SPEED TELESCOPIC VALVE OPERATION

By William H. Buntin

Chief Operator, Sewage Treatment Plant, Panama City, Fla.

Operators who have wasted minutes and energy twirling the handwheel on their telescopic sludge withdrawal valves will benefit by experience at the Panama City, Fla., sewage treatment plant. A simple winch on a stand solved one of the major operating problems—too much water pumped to the digester with the primary clarifier sludge.

The Panama City sewage treatment facility consists of duplicate units in parallel to provide high-rate filtration with secondary settling, and heated sludge digestion. Telescopic valves are provided for use in observing the quality of sludge withdrawn from the primary clarifiers. These telescopic valves were controlled with a handwheel on a threaded shaft requiring 104 turns to raise or lower the valve. In the time required to completely close the valve too much water was withdrawn along with the sludge. Partial opening of the valve to reduce the quantity of water withdrawn was not effective in removing the collected sludge. The additional water required more heat and digestion time than was desirable.

To solve the problem, an A-frame of ¼-in. by 3-in. strap iron was fabricated by electric arc welding. The completed frame was welded to the platform above the telescopic valve. A 7-in. diameter winch with a 3/16-in. aircraft cable was mounted on the A-frame (Figure 1). Attached to the end of the cable was a ¾-in. pipe that screwed into the yoke of the telescopic valve and acted as a stop to prevent pulling the valve out of the pipe stand.

The new arrangement reduced the number of turns to open or close the valve from 104, with the screw-type control, to only 4 with the hand winch. Excess water pumped to the digester was reduced 60 per cent, resulting in a considerable saving in the cost of operation.

Material and labor to make and install the device cost approximately $42.

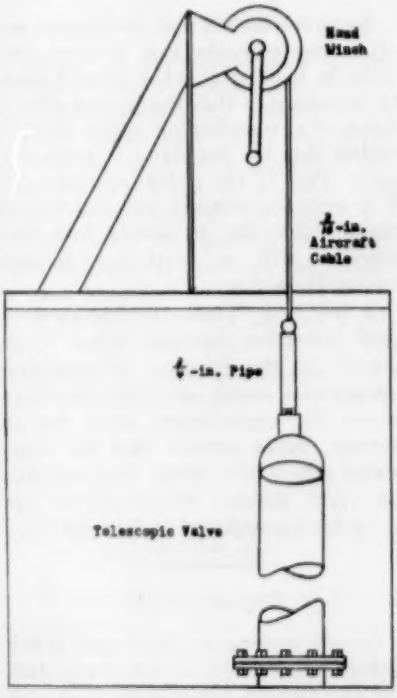


FIGURE 1.—High-speed telescopic valve operation using an A-frame and pulley.

TIPS AND QUIPS

Hatfield Competition Suspended

As reported earlier this year in the Journal, the Hatfield Award competition for sewage treatment plant operation reports was suspended for 1955 by the Federation Board of Control at the Cincinnati meeting. A lack of interest by the majority of operator members of the Federation prompted this action.

The future status of this award is presently under consideration by the Operation Reports Committee.

How's Your Complaint Handling?

Everyone knows that complaints are often unreasonable and without any basis in fact. But what doesn't seem to be known is that the person who is doing the complaining often doesn't realize that his complaint is unreasonable. Part of the public relations job is to help the complainant understand the problem and to satisfy him that someone will at least try to get reasonable action.

A few tips—Train the employee in good telephone manners before he is placed in the position of receiving complaints; make sure the employee knows the organization from top to bottom; make certain that the complaint gets to the person who can take the right action; always follow up, never let a complaint be ignored.

Lagoon Study

Sewage lagoons in North and South Dakota will receive careful study during the various seasons of 1955. A USPHS team of scientists will be active around the lagoons in these two states and the results will be awaited with interest.

This method of municipal sewage treatment is used by 31 cities in North Dakota and 15 in South Dakota. Lagoons are gradually finding a place in the municipal sewage treatment field in other states.

Using Portable Power Tools

The recent rapid trend toward mechanization of all hand labor should benefit by the publication of a new 200-page book by Maurice Reid entitled "How to Use Portable Power Tools." The book describes all types of standard portable electric tools, newly developed machines, and numerous attachments for specialized jobs. Step-by-step instructions on uses and "tricks of the trades" show the craftsman how to turn out more skillful work 12 times faster and with less fatigue than by older hand methods. Numerous instructive photographs should make this book a practical guide for all manual workers. Copies may be obtained from Thomas Y. Crowell Company, New York, N. Y., at $2.95. Unabridged special editions are available at $1.50 each by writing Porter-Cable Co., 55 Exchange Street, Syracuse 8, N. Y.

Wind the Great Destroyer

While the Weather Bureau reports hundreds of windstorms that have caused widespread damage in recent years, the National Board of Fire Underwriters started in 1949 a listing of catastrophes for statistical purposes. These catastrophes, each causing damage of $1,000,000 or more, now number 56. One munitions explosion and an earthquake are listed, but 43 of the catastrophes were due entirely to wind or wind in combination with hail.

The forces of Nature are still mighty and awesome and can strike at anytime.

Microphotometers for Analyses

Light-scattering microphotometers have been used to measure water turbidity. Now it is noted that an improved device has determined turbidity as low as 0.01 p.p.m. Consideration is being given to the possibility of using this type instrument instead of chemical analyses currently made for water quality control. The need for fewer chemicals and man-hours should result in increased efficiency and decreased costs.

Powered End-Gate Saves Back-Ache

Hydraulic elevating end-gates for service trucks should find excellent use by sewer and plant maintenance personnel. The simplified compact lift gates can facilitate the loading and unloading of pumps, tools and other equipment by service crews.

Designed for installation on the rear of a 1½-ton or larger truck, the powered gate can lift or lower loads up to 2,000 lb. Single-lever controls can be located on each side of the truck to control all movements and permit the operator to be on the safe side of the truck. Several excellent safety design features prevent such accidents as overload, unattended movement of gate, and smashed toes. Additional details may be obtained from any of the several manufacturers of this type of equipment.

More Sewage

The rate of water use continues to increase. From 1945 to 1950 it rose approximately 10 per cent to reach the 140-g.p.c.d. level. This increase, coupled with the predicted increase in the adult population over the next 10 years, betokens an ever-increasing volume of waterborne wastes to be treated.

Fire Cooperation

Often fire protection at a sewage treatment plant depends on effective cooperation between the municipal fire-fighting teams and plant personnel. A drill centered on a simulated fire condition will serve to acquaint both plant personnel and the local fire fighters with the location of equipment and special problems that might be encountered.

As a public relations, as well as fire safety angle, how many of the fire fighters know where the sewage treatment plant is located or have been to see it?

INDUSTRIAL WASTE ENGINEER

The city of Dallas, Texas, has an opening for Industrial Waste Engineer 14. Job requirements: Degree in Chemical Engineering or equivalent, plus five years experience involving treatment of industrial wastes. Salary: $411 to $548 per month.

Direct inquiries to Mr. C. Wedgeworth, Chief, Recruitment and Examination, Civil Service Department, Room 412, City Hall, Dallas, Texas.

SUNSHINE STATE NEEDS OPERATORS

Florida's sewage treatment plant construction activities have created a shortage of experienced operators. Primary need is for trained men who are qualified for superintendent or chief operator positions. Those interested should write to David B. Lee, Director, Bureau of Sanitary Engineering, Florida State Board of Health, P. O. Box 210, Jacksonville, Fla.

Reviews and Abstracts*

Method for Determination of Dissolved Oxygen Application to Liquid Bacterial Cultures. By B. Warshowsky and E. S. Schantz. *Anal. Chem.*, **26**, 1811 (1954).

The rotating platinum electrode is reported to be suitable for determining dissolved oxygen in an actively respiring bacterial culture. It is necessary, however, to add 5,000 p.p.m. or more of sodium chloride to the medium during the use of the electrode.

It may be that the apparatus described in the article can be adapted to certain industrial problems for determining D.O.

R. S. Ingols

Cation Exchange Removal of Radioactivity from Wastes. By H. W. Swope and E. Anderson. *Ind. Eng. Chem.*, **47**, 78 (1955).

Low level radioactivity can be removed by sulfonic acid cation exchange resin. Although only 6,000 gal. per cubic foot can be tolerated by the resin before hardness breaks through, at least 260,000 gal. can be passed through 1 cu. ft. with 80 per cent reduction in radioactivity. Various other materials tend to clog the filter after the large volume of passage. The high percentage removal is obtained with a high rate of throughput. R. S. Ingols

Treatment of Chromic Acid Wastes—Evaluation of Methods. By R. F. Ledford and J. C. Hesler. *Ind. Eng. Chem.*, **47**, 83 (1955).

Chromic acid stripping of copper requires removal of copper from the bath or frequent replacement of the chromic acid liquor. The high cost of the chromate plus the problem of waste disposal led to the installation in two places of chromic acid recovery by cation exchange treatment of the used or impure chromic acid solutions to remove metallic impurities. The treated acid solutions are reconcentrated with heat before re-use. The copper is also recovered. R. S. Ingols

Treatment of Spent Sulfuric Acid Pickling Liquors. By A. M. Fradkin and E. B. Fooper. *Ind. Eng. Chem.*, **47**, 87 (1955).

The article contains a discussion of the method for recovering both the iron and acid from a pickling bath using sulfuric acid. The resin is regenerated with hydrochloric acid because the hydrochloric acid can be recovered by heating the iron chloride solution and then the iron residue. The iron oxide resulting can be added back to the furnace charge; the sulfuric acid is used directly in the acid pickling bath. The hydrochloric acid is recycled in the regeneration cycle. R. S. Ingols

Treatment of Formaldehyde Wastes by Activated Sludge Methods. By T. Waldmeyer. *Jour. and Proc. Inst. Sew. Purif.* (Brit.), 52 (1952).

This is the original of a previous article from the *Surveyor* as abstracted in This Journal, **25**, 3, 351 (Mar., 1953).

Preliminary Treatment of Sewage. By J. L. Campbell. *Jour. and Proc. Inst. Sew. Purif.* (Brit.), 69 (1952).

The author makes the academic statement that "when designing a sewage works each set of circumstances demands individual consideration; factors such as the sewerage system in use, the type of secondary treatment contemplated and the system of sludge disposal involved."

In this paper are discussed screening, comminuters, incineration of screenings, and grit removal. The discussion is made up of personal opinions and observations of engineers and plant operators.

Raymond E. Anderson

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 4435 Wisconsin Ave., N. W., Washington 16, D. C.

The Interpretation of Chemical Analyses of Sewages. By J. McNicholas. *Jour. Proc. Inst. Sew. Purif.* (Brit.), 72 (1952).

The most usual reasons for chemical analyses of sewages and effluents are given, followed by a brief description of each of the usual tests, oxygen absorbed, B.O.D., ammoniacal nitrogen, organic and albuminoid nitrogen, oxidized nitrogen, suspended matter, chlorides, and alkalinity, and pH. (See previous abstract in This Journal, **25**, 1, 114 (Jan., 1953).

Raymond E. Anderson

Chemical Oxidation—Some Laboratory Experiments in the Treatment of Chemical Trade Wastes. By G. Taylor. *Jour. and Proc. Inst. Sew. Purif.* (Brit.), 42 (1952).

The use of oxidizing agents in sewage and industrial wastes treatment processes has been principally restricted to odor control and disinfection, with the reduction of B.O.D. generally inconclusive or on an experimental basis. Exceptions are the successful use of chlorine on cyanides and phenols.

This paper deals with experimental work at the Huddersfield sewage works using activated carbon, chlorine, bromine, and ozone. The summary states that all the experiments showed some reduction of the 4-hr. oxygen absorbed figure (oxygen consumed), and that "some reaction had been carried through which may or may not give better purification in the biological treatment stages."

Raymond E. Anderson

Measurement of the Toxicity of Substances to Fish. By D. W. M. Herbert. *Jour. and Proc. Inst. Sew. Purif.* (Brit.), 60 (1952).

The paper is a summary of the variable factors that make difficult the adoption of fixed standards of purity for sewage effluents, especially industrial wastes containing toxic substances. Among these factors are chemical properties of the stream, oxygen concentration, temperature, and pH value.

In experimental work, it is not often possible to compare results of different workers, because of such variations as the duration of the test, the species and age of test animals, the dissolved mineral content of the water used, the concentration of other waste components, etc.

Of interest in the paper are the methods for interpretation of results and the variation of resistance to poison among fish. More information on the effect of such factors is desirable if standard procedures for determining the toxicity of waste waters are to be adopted. In the fine discussion that followed, it was brought out that cyanide was a case in point.

Raymond E. Anderson

The Oxford Sewage Pumping and Purification Scheme—Civil Engineering Aspects. By A. W. Shilston and D. A. H. Everett. *Jour. Inst. Munic. Eng.*, **81**, 3, 145 (1954).

This paper deals with design and constructional problems to date.

Low-Level Works, Littlemore.

A clear and comprehensive account of the design of the works is given. The new works have been constructed next to the existing pumping station on floodable land. The site was enclosed during construction with approximately 300 lineal yards of steel sheet piling, driven in panels of 18-ft. piles, to restrict the ingress of water. Excavation was carried out mainly in open cut, steel piling being driven to support the sides of the excavation where necessary. The cost of this phase is approximately £156,000, excluding land, office and supervisory charges.

Sewage Treatment Works, Sandford.

A general layout plan of these works is given. Since earlier paper certain revisions have been made; namely, a fourth engine-alternator set has been added in the power house; single-stage elutriation in one 45-ft. diameter tank of 13-ft. sidewater depth has been added in the vacuum filtration plant; and the five activated sludge return pumps have been uprated so that with four in operation a return pumping rate of 100 per cent dry-weather flow can be maintained.

The circular tanks have walls monolithic with the base (Reissner's method), designed to withstand the full head of contained liquid, making no allowance for relief from any earth backfill and to withstand active earth pressure when empty. The four flat-bottomed settling tanks are each 80 ft. in diameter and have a side-

water depth of 9 ft. 6 in. Sludge scraping mechanisms are provided.

Each of the six clariflocculators is 60 ft. in diameter and 12 ft. side-water depth, with truncated conical bottom leading to a 12-ft. internal diameter annular sump in which sludge thickening is carried out. Two sludge digestion tanks are provided.

The activated sludge plant installation consists of 40 hopper-bottomed tanks 31 ft. square in plan in four rows of 10 each.

The incoming raw sewage flows down an elevated open channel 5 ft. wide dividing into two 3-ft. wide channels leading to the feed walls.

A comprehensive description of the construction is given, in which each part of the plant is discussed under separate headings.

D. E. PASCOE

Mechanical Filtration of Sewage Effluents. III. Removal of Humus: Further Experiments at Luton. BY A. E. J. PETTET, W. F. COLLETT AND J. I. WADDINGTON. *Jour. Inst. Sew. Purif.* (Brit.), 195 (1951).

Continuous operation for seven months of two semi-scale rapid gravity filters containing, respectively, 2 ft. of graded sand and 2 ft. of graded anthracite, showed that by filtration of humus tank effluent at application rates up to 200 g.p.h. per square foot the average suspended solids content could be reduced by 72 to 98 per cent, with accompanying 50 to 90 per cent reduction in B.O.D. and 17 to 44 per cent reduction in oxygen absorbed from acid permanganate. There was no significant difference between the quality of effluents produced by filtration through sand and through anthracite. About 70 per cent of the D.O. present in the humus tank effluent was absorbed during filtration, but the effluents from the filters always contained at least 10 per cent of the saturation concentration of oxygen.

The filters were backwashed daily, after a preliminary scouring with air, at a rate of 700 g.p.h. per square foot. Loss of head during a 24-hr. filter run averaged 5.6 ft. of water. Experience with the open gravity filters indicated that if the filters were adequately scoured with air and backwashed at regular intervals, chlorination to keep the medium free from accumulations of organic growths would probably be unnecessary.

There was little difference in the quality of effluent produced by filtration through 3.5 ft. as compared with 2 ft. of similarly graded sand.

Sand graded by a commercial supplier so as to correspond as closely as possible to hand-graded material could be used satisfactorily for final tank effluent at Luton.

H. P. O.

Experimental Studies on the Fate of Radioactive Materials in Sewage Treatment. BY E. H. BELCHER. *Jour. Inst. Sew. Purif.* (Brit.), 348 (1951).

Laboratory experiments designed to investigate the fate of five commonly used radioisotopes (Na^{24}, P^{32}, Co^{60}, Br^{82} and I^{131}) during the characteristic processes of sewage treatment are described. The processes studied included primary sedimentation, percolating filters and activated sludge. Adsorption on sludge during primary sedimentation is small for all the isotopes studied. The results for trickling filters and activated sludge processes show a general similarity; adsorption of Na^{24}, Br^{82} and I^{131} is small, whereas P^{32} and Co^{60} are more strongly adsorbed. Studies with P^{32} on percolating filters failed to reveal any measurable radiation effects at a radioactive concentration of 100 mc. per liter on the microorganisms responsible for sewage purification. The significance of the results in the assessment of maximum permissible concentrations of radioisotopes in sewage is discussed.

H. P. O.

Incineration and Alternative Refuse Disposal Processes. BY RALPH STONE AND F. R. BOWERMAN. *Proc. Amer. Soc. Civil Eng.*, **80,** Separate No. 471 (Aug., 1954).

The paper briefly describes forms of refuse disposal and under incineration discusses development, location for best service, by-products, components of the structure, and operating criteria. In greater detail calculations are shown for obtaining mass and heat balance, chamber temperatures, heat energy balance, heat transfer to refractories, and the cooling effect of raw refuse. A number of figures and graphs are included.

W. A. HASFURTHER

Some Economic Aspects of Sewage Works Design. By C. D. C. Braine. *Jour. Inst. Sew. Purif.* (Brit.), 221 (1952).

Increased water usage in England, not only because of industrial and population increases, but also because of increased per capita consumption, is already overloading many even fairly new plants. In addition to the factor of reduction in treatment capacity, there is also the lack of sufficient and suitable labor for plant operation, a matter that is rapidly becoming a compelling reason to reconstruct and modernize many plants. With all charges considered, it now is worth while to spend £5,000 in capital to save the full-time labor of one man, but the financial aspects of any such widespread modernization program present some formidable obstacles.

The British practice of providing storage and later treatment for storm-water flows up to 4 to 5 times the dry-weather flow is discussed, together with the unit costs of construction for plants and sewers of increasing size.

Self-priming low-head siphons are suggested as economical substitutes for costly large penstocks and valves on storm-water tank inlets. Combined grit removal and washing in upward flow tanks of a modified Dortmund type using a small quantity of returned effluent as the washing agent under a blanket of sewage seems to offer economies.

Shallow sedimentation tanks are more economical for the efficiency realized, the actual shape of the tank having little effect on the results obtained. However, for equal areas, and to maintain the same horizontal velocity, a circular tank would have approximately one-half the depth of a square tank. Also, the circular tank would have only one hopper and sludge pipe, whereas the square tank would have three or more of each. On the other hand, sludge collection facilities will cost less for the rectangular tank. Reduced attendance costs for the circular sludge collector, however, usually will make the circular tank more economical, the disparity in its favor increasing with increasing size.

Of several circular sludge collectors studied on a laboratory scale, the spiral, single-arm scraper type proved most efficient. Furthermore, complete sludge removal on each revolution obviates the need for relatively steep sloping floors in such tanks, reducing construction difficulties and costs. The non-radial, spiral scrapers proved suitable not only for primary sludge, but also for secondary and activated sludge, previously thought to be too light to be pushed. The increasing trend to sludge concentration in separate tanks is reducing the necessity for deep sludge hoppers in sedimentation tanks, effecting another construction saving.

Although the author believes that full tiling of trickling filter floors allows better ventilation, and therefore increased dosing rates with attendant economies, there is no authoritative work to support or disprove the view. Circular filters are undoubtedly economical and convenient for small installations, but in larger installations rectangular filters offer several economic advantages. High-rate filters and alternating double filtration provide other means of economy for specific instances.

Long-standing design criteria for sludge digestion and drying seem to be inadequate and need revision upward, particularly as concerns capacity requirements. Furthermore, local weather conditions and the characteristics of individual sludges have too often not been taken into account in designing these facilities. Among the factors to be considered in the economic picture are seeding, digestion temperatures, shape of tank, depth of tank, slope of bottom, location of heating coils, mixing facilities, and gas collection. A design combining a movable-cover circular primary tank with hopper bottom and an annular secondary tank with flat bottom "wrapped around" the primary so that the inlet and outlet piping for both tanks is contained in a small section of the outer tank, seems to offer advantages of construction, heating, and operational economy. Larger installations offer over-all economy in use of dual-fuel or gas engines, despite the costs involved in gas collection and storage. Digestion followed by sludge beds or lagoons is able to compete effectively in England with heat treatment, vacuum filtration, or incineration, because of the specialized machinery required by the last three processes. H. P. O.

Addition Methods of Water Analysis and Their Value in Appraising the Content of Waste Waters. By B. Meissner. *Wasserwirtschaft-Wassertechnik*, **4**, 166 (1954).

About 180 pure compounds were investigated with respect to permanganate oxygen consumed, 5-day B.O.D., chlorine demand, and bromine demand. The following types of compounds were investigated: inorganic nitrogen and sulfur compounds, hydrocarbons, acyclic alcohols, aldehydes, ketones and esters, acyclic acids, cyclic oxygen-containing compounds, cyclic nitrogen-containing compounds, carbohydrates, proteins and their constituent compounds, and dyes. The following types of compounds were practically stable to $KMnO_4$: Acyclic saturated hydrocarbons and their halogen derivatives, monocyclic hydrocarbons, ketones, ethers, esters and monohydric alcohols, saturated mono- and polybasic acids, amides and amino acids, and simple tertiary amines. Most organic substances exhibit a B.O.D., with the exception of dyes, hydrocarbons and a few aromatic nitrogen bases. There was no correlation with permanganate O.C. Chlorine demand parallels the $KMnO_4$ O.C. with the exception of nitrogen-containing substances which are more strongly attacked. Bromine demand was exhibited only by phenols, unsaturated organic acids, primary and secondary aromatic amines, and dyes. The $KMnO_4$ O.C. per unit weight of organic matter of specific wastes can be used to estimate the general nature of the organic pollution. Peter K. Mueller

A Recorder for the Determination of Surface Active Substances in Water and Sewage. By O. Hettche. *Vom Wasser*, **20**, 137 (1953).

Surface-active agents in sewage reach water supplies. The degree of pollution can be continuously measured by changes in surface activity. A ring tensiometer incorporated into an automatic sampling and recording device can measure surface activity every 3 min. The apparatus detected 0.007 p.p.m. of a household detergent. Results of measurements along the Elbe in Hamburg correlate well with location of sewer outfalls.

Peter K. Mueller

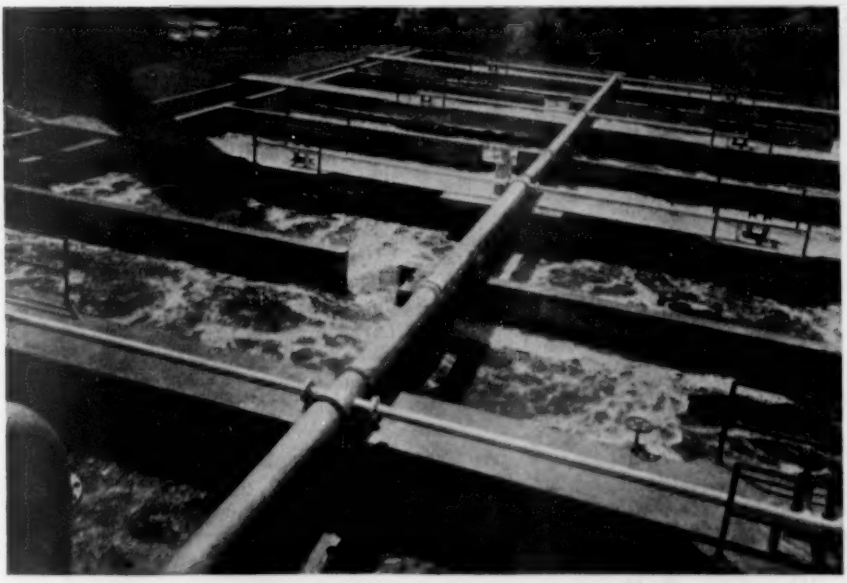
High-Rate Sludge Digestion. By Clair N. Sawyer and Harold E. Schmidt. *Jour. Boston Soc. Civil Eng.*, **42**, 1, 1 (1955).

Laboratory studies were carried out of the various high-rate sludge digestion methods described in recent literature. Detention time proved to be the most important consideration in the operation of high-rate sludge digestion units. Satisfactory operation was obtained with detention periods as short as 11 days. Volatile solids destruction declines considerably with decreasing detention time and gas production suffers accordingly. The pH and alkalinity of digestion mixtures increases as the total solids increases in the feed sludge. Also, the pH and alkalinity are a function of detention time, decreasing with shortened detention periods.

Permissible solids loadings are a function of the concentration of solids in the sludge fed to the digester because of limitations imposed by detention time. For a sludge with 75 per cent volatile matter and digestion temperature of 95° C., the following maximum loadings are indicated:

Sludge Conc. (%)	Max. Digester Loading (lb./cu. ft./mo.)
2	3.3 to 4.6
4	6.7 to 8.9
6	10.3 to 14.3
8	13.5 to 19.3

High-rate digestion will find practical applications where facilities are available for continuous handling of the mixed liquor displaced by additions of raw sludge. Most satisfactory operation will be obtained by feeding thickened sludges, which will produce mixed liquor overflow of at least 4 per cent solids. Thickened sludges are necessary to obtain sufficiently long detention periods (15 days) to allow satisfactory reduction of volatile solids, maximum gas production and elimination of supernatant liquor. Where adequate thickening of sludges (8 to 10 per cent solids) cannot be obtained, secondary units for dewatering of the digested sludge will be required. Elutriation of digested sludges prior to chemical conditioning for vacuum filtration will become a necessity because all biochemical degradation products contributing to alkalinity will be concentrated in the sludge liquor. H. P. O.



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Proceedings of Member Associations

NORTH CAROLINA SEWAGE AND INDUSTRIAL WASTE ASSOCIATION

The 1954 Annual Meeting of the North Carolina Sewage and Industrial Waste Association was held in the George Vanderbilt Hotel, Asheville, N. C., on November 8–10, 1954, in conjunction with the North Carolina Section AWWA. Total registration for the combined meeting was 255.

Among the papers presented were the following:

"Development of Adequate Water and Sewer Rate Structures," by Richard Hazen, Consulting Engineer, New York, N. Y.

"Operation of Municipal Sewage Treatment Plant at Salisbury, N. C.," by John N. Leslie, Jr., Superintendent.

"Water and Sewer Service Connection Charges," by D. J. Gore, Superintendent, Public Works Commission, Fayetteville.

"Sewer Service Charges Applying to Unusual Commercial and Industrial Wastes," by R. S. Phillips, Assistant Superintendent, City Water Dept., Charlotte.

Officers elected for the ensuing year were as follows:

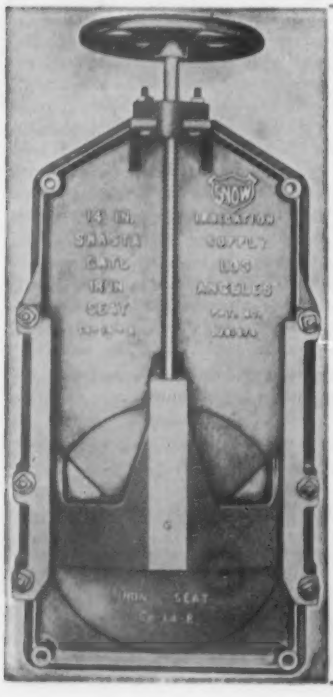
Chairman: S. E. Harris, Winston-Salem.

Vice-Chairman: R. S. Phillips, Charlotte.

FSIWA Director: E. C. Hubbard, Raleigh.

Secretary-Treasurer: W. E. Long, Jr., Raleigh.

E. C. HUBBARD,
Secretary-Treasurer



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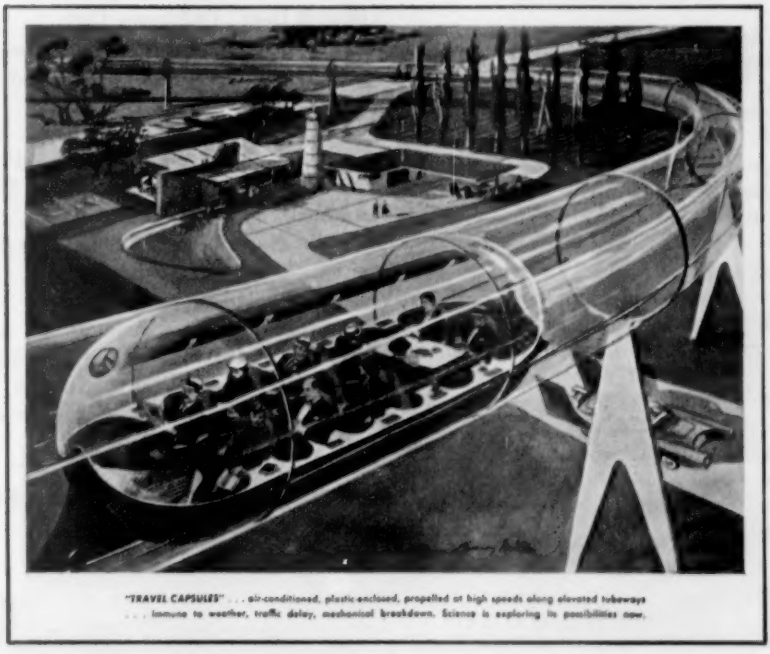

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OKLAHOMA WATER, SEWAGE AND INDUSTRIAL WASTES CONFERENCE

The 1954 Annual Meeting of the Oklahoma Water, Sewage and Industrial Wastes Conference was held November 16–19, 1954, at Oklahoma A & M College, Stillwater, Okla., in conjunction with the 28th Water and Sewage Short Course and the 1954 Industrial Wastes Conference. Registration for the combined meetings totaled 160.

Lectures, panel discussions and laboratory sessions comprised the bulk of the program. Papers of special interest to sanitation personnel were presented on safety, biocatalysts, sewage gas utilization and the use of concrete in water and sewage construction.

At the special industrial waste sessions, the following papers were presented:

"Legislative Prospects for Water Pollution Abatement," by L. J. Clarke, Sanitary Engineer, State Health Dept., Oklahoma City.

"Pryor Creek Improvement Association Activities," by Curtis E. Moutrey, Tulsa.

"Grand River Dam Authority Activities," by R. G. Medlock, Field Superintendent, Grand River Dam Authority.

"The Nature and Status of Air Pollution," by R. P. Kuykendall, Infilco, Inc., Tulsa.

"Procedures for Handling and Treating Industrial Wastes at Tinker Air Force Base," by Charles S. Moore, Sanitary Engineer, Tinker Air Force Base, Oklahoma City.

"Underground Brine Disposal," by W. S. Morris, Vice-President, East

(*Continued on page 250a*)

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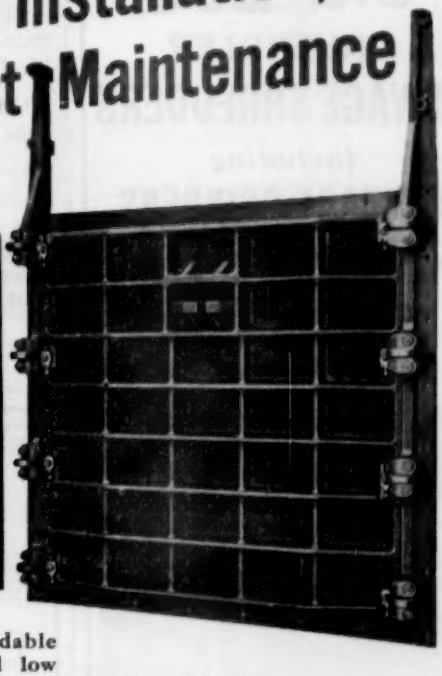

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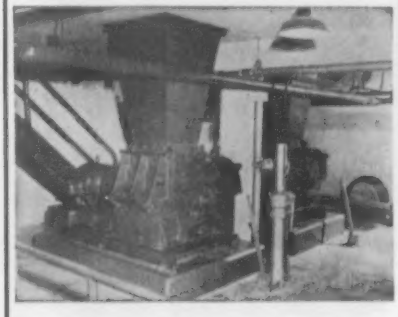

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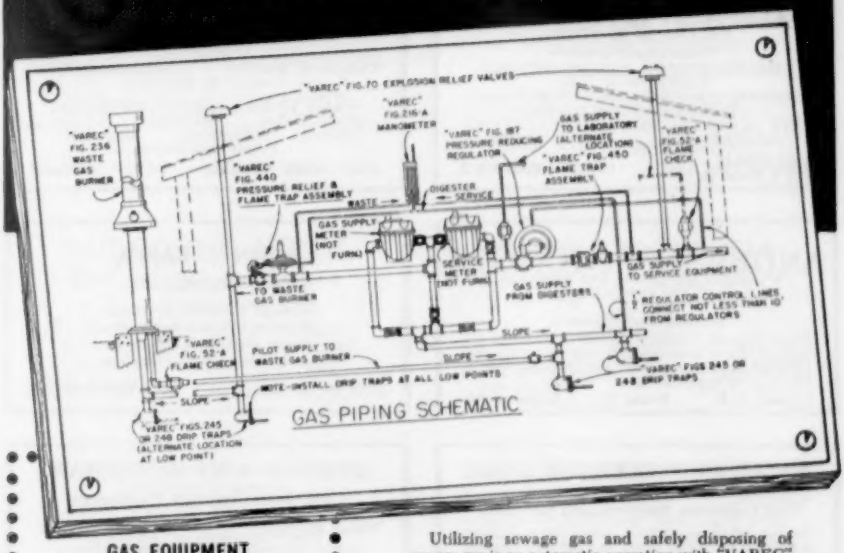
"VAREC" FIG. 70 EXPLOSION RELIEF VALVES
"VAREC" FIG. 236 WASTE GAS BURNER
"VAREC" FIG. 440 PRESSURE RELIEF & FLAME TRAP ASSEMBLY
"VAREC" FIG. 216-A MANOMETER
"VAREC" FIG. 187 PRESSURE REDUCING REGULATOR
GAS SUPPLY TO LABORATORY (ALTERNATE LOCATIONS)
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
"VAREC" FIG. 52-A FLAME CHECK
WASTE
DIGESTER SERVICE
GAS SUPPLY METER (NOT FURN.)
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GAS SUPPLY TO SERVICE EQUIPMENT
TO WASTE GAS BURNER
GAS SUPPLY FROM DIGESTERS
REGULATOR CONTROL LINES CONNECT NOT LESS THAN 10' FROM REGULATORS
"VAREC" FIG. 52-A FLAME CHECK
PILOT SUPPLY TO WASTE GAS BURNER
SLOPE
SLOPE
SLOPE
NOTE-INSTALL DRIP TRAPS AT ALL LOW POINTS
"VAREC" FIGS. 245 OR 248 DRIP TRAPS
"VAREC" FIGS. 245 OR 248 DRIP TRAPS (ALTERNATE LOCATION AT LOW POINT)
GAS PIPING SCHEMATIC

GAS EQUIPMENT SPECIFICATIONS

PRESSURE RELIEF AND FLAME TRAP ASSEMBLY
"VAREC" Fig. No. 440

FLAME TRAP ASSEMBLY
"VAREC" Fig. No. 450

FLAME CHECK
"VAREC" Fig. No. 52A

EXPLOSION RELIEF VALVES
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WASTE GAS BURNER
"VAREC" Fig. No. 236

DRIP TRAPS
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Purcell, Lee T.
Riddick, Thomas M.
Ripple & Howe
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Smith & Gillespie
Stanley Engineering Company
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